

**2013 ANNUAL COMPREHENSIVE REPORT
OF GROUND AND SURFACE WATER QUALITY
GREENFIELD ENVIRONMENTAL MULTISTATE TRUST
FORMER TRONOX SODA SPRINGS, IDAHO FACILITY**

April 17, 2013

Prepared by:



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SALT LAKE CITY, UTAH



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April 17, 2013
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**RE: TRANSMITTAL: REMEDIAL ACTION 2013 ANNUAL COMPREHENSIVE
REPORT OF GROUND AND SURFACE WATER QUALITY - GREENFIELD
ENVIRONMENTAL MULTISTATE TRUST - FORMER TRONOX SODA
SPRINGS, IDAHO FACILITY**

Dear Marc:

Enclosed please find transmitted the Remedial Action 2013 Annual Comprehensive Report of Ground and Surface Water Quality for the Tronox Soda Springs, Idaho Facility. This document consist of: 1) an evaluation of the most currently available (May and October 2012) ground water quality distribution at on- and off-site locations for selected parameters; 2) an evaluation of ground and surface water quality changes with time; 3) projected decay trends for selected COC and wells for the period between 1997 and 2012 and a second set spanning 2004 through 2012, and; 4) conclusions regarding the effects to ground water from remedial actions and reclamation efforts to date. We have integrated selected results from the Monsanto sampling and Evergreen sampling events that took place in June 2012 to this year's report to broaden the understanding of off-site contaminant migration in the ground water.

We appreciate the opportunity to work with you on this project. If you have any questions regarding this transmittal, please contact us.

Very truly yours,

Global Environmental Technologies, LLC

John S. Brown, P.G., L.P.I.
Principal/Owner



Attachments: Remedial Action 2013 Annual Comprehensive Report of Ground and Surface Water Quality

xc: Bill Ryan — EPA Region X – (4 hard copies; 4 -CD copies)
Doug Tanner — IDEQ Pocatello –hard copy/CD copy
Dean Nygard — IDEQ Boise - hard copy/CD copy
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TABLE OF CONTENTS

<u>Section</u>	<u>Page No.</u>
Executive Summary.....	ES-1
1.0 INTRODUCTION.....	1
1.1 Ground Water Monitoring Program.....	1
1.2 Remedial Action Completion.....	3
1.2.1 Liquid Source Elimination.....	4
1.2.1.1 Scrubber Pond.....	4
1.2.1.2 S-X Pond.....	5
1.2.1.3 Calcine Pond.....	5
1.3 Remedy Completion.....	6
1.4 Ground Water COCs.....	7
2.0 SUMMARY OF SITE HYDROGEOLOGY.....	8
2.1 Site Hydrogeology.....	8
2.1.1 Salt Lake Formation.....	9
2.1.2 Alluvium.....	9
2.1.3 Basalt Aquifer.....	9
2.1.3.1 Hydraulic Conductivities of Basalt Aquifer.....	10
2.1.3.2 Estimated Ground Water Velocities.....	12
2.2 Direction and Rate of Ground Water Flow.....	12
2.3 Site Water Levels and Site Precipitation.....	14
3.0 GROUND WATER SAMPLING.....	15
3.1 Ground Water Point of Compliance.....	15
3.2 Ground Water Sampling and Analysis Plan.....	15
3.2.1 Low-Flow Purge Sampling Methods.....	16
3.3 QA/QC Data Review	17
4.0 CURRENT GROUND AND SURFACE WATER QUALITY.....	18
4.1 Background Water Quality and Type.....	18
4.2 Common Ion Distributions in Ground Water.....	19
4.3 General Ground Water Quality Parameters.....	19
4.3.1 pH.....	19
4.3.2 Total Dissolved Solids.....	20
4.3.3 Turbidity.....	21
4.4 Selected Major Ions in Ground Water.....	21
4.4.1 Chloride.....	21
4.4.2 Nitrate Plus Nitrite.....	21
4.4.3 Sulfate.....	22
4.5 Selected Metals in Ground Water.....	23
4.5.1 Arsenic.....	23
4.5.2 Manganese.....	24
4.5.3 Molybdenum.....	24
4.5.4 Vanadium.....	26
4.6 Organic Compounds in Ground Water.....	27

TABLE OF CONTENTS (Continued)

<u>Section</u>	<u>Page No.</u>
4.6.1 Total Petroleum Hydrocarbons.....	27
4.6.2 Tributyl Phosphate.....	28
5.0 CONCENTRATION TRENDS WITH TIME.....	29
5.1 General.....	29
5.1.1 Fate and Transport of Graphed Chemical Parameters.....	29
5.2 Trends for On-Site and Point of Compliance Wells.....	33
5.2.1 Common Ions and General Indicators.....	33
5.2.2 Metals Concentration Trends.....	38
5.2.3 Organics.....	42
5.2.4 Conclusions of On-Site Well Concentration Trends.....	43
5.3 Off-Site Well Concentration Trends.....	44
5.3.1 Common Ions and General Indicators.....	45
5.3.2 Off-Site Metal Concentration Trends.....	46
5.3.3 Organics.....	49
5.3.4 Conclusions of Off-Site Well Concentration Trends.....	49
5.4 Off-Site Surface Water Quality Concentration Trends.....	50
5.4.1 Common Ions and General Indicators.....	51
5.4.2 Metals Concentration Trends.....	53
6.0 PROJECTED CONCENTRATION DECAY TRENDS	55
6.1 General	55
6.2 Analytical Method	56
6.3 Results of Regression Analysis.....	57
7.0 CONCLUSIONS.....	62
8.0 RECOMMENDATIONS.....	67
9.0 REFERENCES.....	70

TABLES

<u>Table Number</u>	<u>Title</u>
Table 1-1	Monitor Well Construction Data
Table 1-2	Maximum Concentrations of COC and Most Current Concentrations in Wells and Off-Site Springs
Table 3-1	Sampling History and Sampling Rationale for Remedial Design/Remedial Action Ground Water Sampling
Table 5-1	Chronology of Process Changes

TABLES (cont.)

<u>Table Number</u>	<u>Title</u>
Table 6-1	Projected COC Trends Based on November 1997 through September 2012 Data
Table 6-2	Projected COC Trends Based on May 2004 through September 2012 Data

FIGURES

<u>Figure Number</u>	<u>Title</u>
Figure 1-1	Approximate Trust Property Boundary Map
Figure 1-2	Contours of Ground Water Level Elevations – May 2012
Figure 2-1	Contour Of Regional Ground Water Level Elevations May To June 2012
Figure 2-2	Annual Precipitation – Soda Springs, Idaho 1990 through 2012
Figure 2-3a,b	Water Levels Versus Time, Tronox On-Site Wells Following LSE and Pond Reclamation
Figure 4-1	Contour of pH in Ground Water – May 2012
Figure 4-2	Contour of TDS in Ground Water – May 2012
Figure 4-3	Contour of Chloride in Ground Water – May 2012
Figure 4-4	Contour of Nitrate in Ground Water – May 2012
Figure 4-5	Contour of Sulfate in Ground Water – May 2012
Figure 4-6	Contour of Arsenic in Ground Water – May 2012
Figure 4-7	Contour of Manganese in Ground Water – May 2012
Figure 4-7a	Approximate Location Of Molybdenum Exceeding Risk Levels In Shallow Ground Water May To June 2012

FIGURES (Contd.)

<u>Figure Number</u>	<u>Title</u>
Figure 4-8	Contour of Molybdenum in Ground Water – May 2012
Figure 4-9	Contour of Vanadium in Ground Water – May 2012
Figure 4-9a	Approximate Location Of Vanadium Exceeding Risk Levels In Shallow Ground Water May To June 2012

APPENDICES

APPENDIX A-	GRAPHS OF GROUND AND SURFACE WATER QUALITY VERSUS TIME
APPENDIX B-	COC CONCENTRATION TRENDS WITH TIME AND PROJECTED TRENDS

EXECUTIVE SUMMARY

Kerr-McGee operated a vanadium plant between 1963 and January 1999. Ground water contamination originating from former plant operations was investigated during a Remedial Investigation/Feasibility Study conducted between 1991 and 1996. Ground water contaminants of concern (COC) demonstrating health risks from human consumption included arsenic, manganese, molybdenum, tributyl phosphate, total petroleum hydrocarbons and vanadium.

Most of the site-related contaminants were identified in the ground water beneath property owned by Kerr-McGee. However, molybdenum and vanadium migrated from the site in the ground water to properties off-site that are not currently controlled by the previous site owners at concentrations that exceed risk-based concentrations (RBC).

The EPA-selected remedy for the Kerr-McGee Chemical Superfund Site was elimination of liquid discharges from plant operations, consuming stockpiled waste products to produce vanadium and capping the calcine. Calcine is the solid waste left over from the vanadium leaching circuit. The remedy requires semiannual monitoring of the ground water, monitoring of selected surface water sites and completion of an annual comprehensive evaluation report of results to verify successful implementation of the site remedy.

Industrial ponds were taken out of service between 1995 and 1997. The remedy to eliminate process liquid discharges from vanadium operations to the ground water was completed in 1997. Kerr-McGee constructed an engineered on-site landfill in 1997 and removed sediments down to native soils from two of the largest waste ponds and compacted these wastes in the landfill. Conditions beneath these ponds are unknown (S-X pond and scrubber pond) because these locations were never investigated during the RI/FS. Ground water results from 2012 suggest that these are areas that continue to contribute site contaminants to ground water.

Kerr-McGee failed in its attempt to process the calcine tailing into a marketable fertilizer product. The revised remedy and amended Record of Decision in 2000 allowed for capping of about 22 acres of calcine waste on the east side of the industrial facility between the plant site and the 10-acre pond. A large volume of calcine and other industrial waste from historic vanadium processing remain in place and untreated across the industrial site. The vanadium plant that was dismantled in 2002 and areas surrounding the plant remain additional potential sources of COC to ground water. East of the calcine cap is the 10-acre pond that currently contains more than 20,000 yards of vanadium process wastes and liquid.

In September 2002, EPA completed the first 5-year review for the site and concluded that contaminant levels in the ground water decreased at most locations following remedy implementation. Following the period of this 5-year review, the rate of concentration change in the ground water slowed considerably. In some cases, ground water concentrations increased, or spiked around 2006. Based on these observations, the second 5-year review completed during 2007 stated that a protectiveness determination of the remedy could not be completed because levels of COC in ground water and surface water remained above cleanup goals, and concentrations appeared to increase in some locations. COC trends, such as those noted near the uninvestigated pond basins and at other locations called into question whether achieving the cleanup goals for the site in the foreseeable future in absence of further actions was possible.

Ground water monitoring since completion of the remedy shows that the largest continued impacts to ground water occur near the former scrubber and S-X pond basins. Increased concentrations in some well locations appear to correlate with larger measured annual precipitation in 2006, 2009 and in 2011.

Organic compounds decreased following elimination of the ponds, but levels continue to exceed risk-based concentrations (RBC). Concentrations of arsenic in ground water exceed risk standards only near the former S-X and scrubber ponds. Manganese

concentrations decreased with time in nearly all wells following 1997 with exception of a few wells.

Off-site springs (Finch and Big Springs) fell below the RBC for molybdenum in 2009. These springs are predicted to remain below these levels into the future. Vanadium concentrations in Finch Spring remain elevated but are a percentage of the RBC, while vanadium is near the detection limit in Big Spring. The City of Soda Springs water supply contains very small concentrations of vanadium based on 2012 water quality results. Data suggest that nitrate concentrations are increasing with time.

Vanadium and molybdenum continue to exceed clean up levels at most of the on-site and off-site monitoring wells monitored by the MST with few exceptions. Ground water results from the Evergreen and Monsanto sites for 2012 show that ground water concentrations of molybdenum and vanadium exceeding the RBC migrate off the MST property onto Monsanto, City of Soda Springs and private properties that lack institutional controls for ground water consumption. Monsanto wells provide enough information to define the western boundaries of the site contaminants in ground water to the southern Monsanto property boundary. The eastern boundaries of ground water COC exceeding the RBC are not as well understood. Monsanto well TW-67 (installed in 2011) now defines the southern-most known extent of plant site contaminants in ground water.

Regression analysis shows that ground water concentrations of molybdenum and vanadium in the wells monitoring the former S-X and scrubber ponds will exceed the clean up levels for at least 20 years to more than 100 years following the remedy with varying degrees of certainty. This period of time is longer than previous ground water modeling estimates completed for the remedial investigation. Vanadium is projected to exceed the RBC in most wells for a longer period than molybdenum. In some cases, due to increasing concentration levels, the time to reach clean up cannot be projected with certainty.

1.0 INTRODUCTION

1.1 Site Background

In January 2009, Tronox, the PRP and owner of the Soda Springs, Idaho vanadium plant at the time, filed for reorganization under Chapter 11 of the U.S. Bankruptcy Code due to its extensive, legacy environmental liabilities throughout the country. In February 2011, a reorganized Tronox emerged from bankruptcy after entering into a settlement agreement with EPA and a number of State governments, including the State of Idaho. Under the consent decree and environmental settlement agreement, Tronox relinquished ownership of hundreds of contaminated sites throughout the country and provided initial funds to perform critical cleanup activities at those sites. Greenfield Environmental Multistate Trust, LLC, Trustee of the Multistate Environmental Response Trust ("MST"). The MST was created as a part of that settlement for the purposes of: taking ownership of hundreds of Tronox legacy sites; managing limited initial cleanup funds; and addressing the most pressing environmental issues at the properties. The beneficiaries of the Multistate Trust are the EPA and the States where Tronox contaminated sites are located throughout the country. The superfund site that includes about 90 acres of "Plant area" and adjacent Tronox-owned property was transferred to the MST as part of the settlement agreement.

1.1 Ground Water Monitoring Program

Tronox (formerly Kerr-McGee) monitored water levels and water quality in both on- and off-site wells and selected springs on a semiannual basis through 2010. The property was transferred on 14th day of February, 2011 from Tronox as debtors and debtors in possession in the Bankruptcy Cases to the MST, and the MST continues to monitor ground water on the same semiannual basis, as is required by the Record of Decision.

Data reports with sample results and analysis are also presented to the EPA and IDEQ on a semiannual basis. Validation reports that included the 2012 data incorporated into

the Remedial Design/Remedial Action (RD/RA) database were issued to EPA, IDEQ and the Trust on July 27, 2012 and on December 12, 2012. The database is not included in this report, and the reader should refer to the data contained within those validation reports in conjunction with this document. The RD/RA database contains sample analytical data supplied by the laboratory following the completion of the Remedial Investigation/Feasibility Study (RI/FS) study, and was prepared at the request of Region 10 EPA on September 23, 1997.

Monitor wells were installed at strategic locations to monitor specific surface water impoundments, aquifer units, downgradient off-site locations, and the vanadium plant facility as a whole. Locations of on- and off-site well placements and screen location depths are shown in Table 1-1. These data are also presented in previous technical memoranda and work plans (Dames & Moore, 1991 a, b and 1992), (GET, 2010). Table 1-1 also presents the details of three of the 2-inch monitoring wells located within the City of Soda Springs Industrial Park that is adjacent to the MST property. These wells were monitored by the City of Soda Springs in 2012 and are evaluated with these results.

Location of the MST site and property owned by MST is shown on Figure 1-1. Locations of all monitoring wells installed during the remedial investigation (RI) are shown on Figure 1-2. Figure 1-2 also presents measured water level elevations and ground water gradients in May 2012 along with the Evergreen wells.

Thirteen (13) of the eighteen (18) RI/FS wells are designated "shallow" wells with total depths of 45 to 73 feet. Four wells are designated "intermediate-depth" wells with total depths of 100 to 173 feet. One well (KM-19) is completed on-site to a total depth of 230 feet and designated as a "deep" well as it fully-penetrates the basalt bedrock sequence.

The shallow wells are completed with 10 feet of well screen that is set in the uppermost-defined basalt flow or interflow zone. Shallow wells were completed within the first occurrence of ground water that was encountered while drilling. On-site shallow wells

include wells KM-1, KM-2, KM-3, KM-4, KM-5, KM-6, KM-7, KM-8, KM-9, and KM-13. Off-site shallow wells include KM-15, KM-16 and KM-17. Evergreen wells are all shallow wells that were completed within the first occurrence of ground water encountered while drilling and include wells EV-1 through EV-4. Water in the Evergreen wells is found within alluvial gravels, cinders, and broken basalt to the west of the Finch Spring fault scarp.

The intermediate-depth wells are completed with 20 feet of well screen that is set in a deeper basalt flow identified across the site through geophysical interpretation. On-site intermediate depth wells include KM-10, KM-11, and KM-12. The off-site intermediate-depth well is designated KM-18.

1.2 Remedial Action Completion

A complete discussion of the remedial action completion activities is described in the Draft Remedial Action Completion Report Revision I (GET, 1999), and the Draft Remedial Action Completion Report for Calcine Capping, 2000 through 2001 (GET, 2003). Remedial Action for the Kerr-McGee vanadium facility addressed the selected site remedy from the Record of Decision (ROD, September 1995) and subsequent amendment to the ROD (July 2000). The Remedial Action for the vanadium plant included:

- Elimination of uncontrolled liquid discharges from the site;
- Landfilling solids from the scrubber and S-X ponds at an on-site landfill;
- In-place capping of the wind-blown calcine, roaster reject, reject fertilizer, and active calcine tailings during 2000 and 2001;
- Semi-annual ground water monitoring to determine the effectiveness of source control, and;
- Establishment of institutional controls in affected off-site areas to prevent ingestion of ground water for as long as the ground water exceeds the risk-based concentrations (RBC).

1.2.1 Liquid Source Elimination

The ROD required Kerr-McGee Chemical to implement Liquid Source Elimination (LSE) to eliminate the uncontrolled releases of process water to ground water. During 1993, the unlined magnesium ammonium phosphate (MAP) ponds were removed from service and covered. This action had an immediate effect on water quality in nearby well KM-5. Three larger unlined ponds at the facility were either eliminated or replaced to accomplish LSE between 1995 and 1997. These three ponds included the roaster scrubber pond, S-X raffinate pond, and the calcine pond (s).

LSE has clearly improved ground water quality, but will not bring COC into full compliance with RBCs at each one of the locations within a predictably reasonable period of time. Residual contamination above RBCs will persist into the future at some locations unless further action is taken. This is particularly true in areas near the S-X pond and the scrubber pond basins that were never investigated prior to remedy implementation, or sampled following removal of the pond sediments. Ten years following the elimination of these ponds, the concentrations of molybdenum in the ground water at the plant site were reduced by 55 to 90 percent and the concentrations of vanadium were reduced by 50 to 65 percent (GET, 2010). This reduction, however, is not enough to achieve risk-based concentrations in the ground water. Ground water COC concentrations remain one or more magnitudes above risk-based levels in 2012 at most on-site monitored locations, despite the elimination of the ponds by 1997.

1.2.1.1 Scrubber Pond

Wet scrubbers controlled air emissions from the vanadium roasters since the plant began operating in 1963. The solids collected in the scrubbers and in the discharge water were pumped to various scrubber water ponds. This management practice resulted in an uncontrolled release of the process water to ground water, and left the solids from the process impounded in each pond. The scrubber sediments from the former pond on the east side of the facility were impounded in the on-site landfill,

constructed during 1997. An older scrubber pond located near well KM-5 has been covered with the waste remaining in-place.

The wet scrubbers were replaced by a baghouse system on each roaster in 1997. The baghouse collected particulate emissions without the use of water. Solids collected in the baghouse were impounded with the calcine. The result of the installation of the baghouse system was the elimination of the scrubber pond. This allowed for the excavation and placement of the roaster scrubber solids in the landfill and the closure and reclamation of the roaster scrubber pond.

The vanadium plant and supporting baghouse facilities were dismantled between October 2001 and February 2002. The footprint of the vanadium plant was covered with limestone fines and recontoured to provide positive drainage away from the site of the former facility.

1.2.1.2 S-X Pond

Kerr-McGee constructed 20 acres of double-lined ponds in 1995 and 1997 to contain the S-X raffinate stream. Use of the unlined S-X pond was discontinued by 1996 and the sediment was pushed into a pile when the bottom was dry. The S-X pond sediments were excavated from the pond to native soil and impounded in the on-site constructed landfill in 1997. The 5-acre ponds were reclaimed in 2004, while the 10-acre pond remains at the site and contains the plant wastes excavated from the two storm water ponds and the two 5-acre ponds. The 10-acre pond also contains a volume of 800,000 to 2.4 million gallons of mixed residual raffinate water and precipitation.

1.2.1.3 Calcine Pond

Historically, calcine was deposited in the impoundment area by mixing the solids from the vanadium leaching process with water and pumping the slurry to the calcine impoundment. The water used in this operation infiltrated through unlined calcine

ponds. Kerr-McGee installed a mechanical dewatering system to separate the water and the calcine in 1997, eliminating the pond. No calcine was produced following closure of the plant in 1999 and the calcine impoundment on the east side of the site was capped with a synthetic cover in 2001. Calcine ponds on the west side of the site include about 250,000 tons (estimated) of waste material which remains uncapped.

1.3 Remedy Completion

The S-X pond was taken out of service during 1996. However, all of the remedial investigations were concluded by April 1995 and the S-X pond basin conditions below the removed sludges were never considered. During November 1996, the S-X pond sediments and underlying soils were dozed to the south end of the pond and covered with plastic. This action allowed an extended period for the S-X solids to dry and consolidate.

The scrubber pond was taken out of service in April 1997 and was drained prior to the sediment thickness investigation. The conditions beneath the scrubber pond basin were never investigated during the remedial investigations phase and subsurface conditions in the basin are unknown. The scrubber solids were excavated, worked into windrows and piles in the scrubber pond basin to accelerate drying, and later removed to the engineered landfill.

Kerr-McGee excavated and transported S-X and scrubber pond sludge to an engineered landfill constructed during September 1997. Prior to compaction in the landfill, the wastes were mixed at a ratio of 3:1 scrubber to S-X solids to achieve optimum moisture for compaction. During the last week of September 1997, the Idaho Department of Environmental Quality (IDEQ) inspected the pond basins and determined that all of the pond solids had been removed from the native soils lining the pond basins. Several feet of clean native soil were placed in the pond basins to support growth of a vegetative cover. The overall site slopes were graded and sloped to promote runoff away from the preexisting pond locations.

Pond reclamation activities occurred during the last week of September and during the first week of October 1997. Following removal of sediment materials from the pond basins and approval of closure from the IDEQ, completeness of sediment removal from pond basins was documented with photographs and no test samples were obtained.

1.4 Ground Water COC

The six contaminants of concern (COC) that were identified in the Risk Assessment (EPA, 1993) include arsenic, manganese, molybdenum, tributyl phosphate, total petroleum hydrocarbons, and vanadium. Table 1-2 presents a range of concentrations for COC at the POC wells, showing both the largest historic concentrations and the May 2012 concentrations. The May 2012 concentrations are of interest because this time approximately corresponds with sampling at the Monsanto and the Evergreen sites and provides an opportunity to collectively assess the data from all three sites.

2.0 SUMMARY OF SITE HYDROGEOLOGY

2.1 Site Hydrogeology

Ground water beneath and downgradient from the MST site is found within the basalt sequences, the basalt interflow zones, and within limited areas of the alluvium. Ground water also exists within the Tertiary Salt Lake Formation that underlies the basalt. All of the on-site and off-site monitor wells installed as part of the Kerr-McGee RI/FS are completed at various depths within the basalts and basalt interflow zones, as shown in Table 1-1. Evergreen wells are also listed on this table. These wells are located below the Finch fault scarp and intersect younger sequences, including formation rock (freshwater limestone) originating from Formation Springs and saturated rounded gravels and cinders. Although ground water occurs in the Salt Lake Formation and within a limited area of the alluvium on-site, the basalts are considered the principal aquifer beneath the MST site and the Monsanto site to the west. Monsanto production wells extract ground water from the basalt aquifer.

The hydrogeologic properties of the basalts and interflow zones were characterized during the Kerr-McGee RI/FS, using:

- Geologic, geophysical, hydraulic head, hydraulic gradient, and hydraulic conductivity parameters from the installed wells;
- Hydraulic response data observed in the monitor wells, and;
- Observation and testing data from 14 on-site monitor wells, 4 off-site monitor wells and 5 on-site coreholes.

2.1.1 The Salt Lake Formation

The Tertiary Salt Lake Formation is comprised of tuffaceous sandstones, conglomerates and limestones that yield small amounts of ground water for domestic and stock purposes, and are unpredictable as a water-supply source. The Salt Lake Formation is

not considered part of the shallow ground water system. The Salt Lake Formation was investigated on-site in corehole CH-3 from 231 to 250 feet (total depth of corehole CH-3) and was found to consist of fractured quartzite, sandstone, and clay. Packer testing resulted in a hydraulic conductivity determination of 0.77 ft/day. This result is within, but at the low end of the range of packer-test hydraulic conductivities estimated for the deeper part of the overlying basalt sequence. No wells at the MST site are completed within the Salt Lake formation.

2.1.2 Alluvium

Seismic refraction studies and drilling performed as part of the RI indicated that alluvium is thickest and extends to the greatest depth on the eastern side of the plant facility. Based on geologic data from well KM-2, an area of thin saturated alluvium overlies the basalt in the eastern part of the MST facility where the elevation of the basalt/alluvium contact falls below the elevation of the water table. Well KM-2 is screened across the basalt/alluvium contact. The area of saturated alluvium appears to be limited near the east side of the facility, extending to the north and south of the capped calcine tailings. The alluvium has not been noted to contain ground water at other locations on the MST site.

2.1.3 Basalt Aquifer

The basalts and interflow zones of the mid-Pleistocene Blackfoot Lava Field comprise the principal aquifer beneath the site. All of the on-site monitor wells, with the exception of well KM-2, are screened exclusively within these basalts and interflow zones. The basalt sequence at the site, described in the RI is comprised of five identifiable basalt flows (Basalts Nos. Qb₁ through Qb₅) and associated interflow zones (Interflow Zones Nos. I₁ through I₄). Two younger basalts (Qb_{5a} and Qb_{5b}) and associated interflows were identified to the south and west of the site and are believed to have occurred as post-faulting flows. These basalts and interflow zones are believed to be stratigraphically similar to basalt flows identified at the Monsanto Site by Golder (1985 and 1992a).

However, the hydrogeologic characteristics of the basalt flows between the two sites appear to be different. Notable differences include:

- Magnitudes of hydraulic conductivities of the basalt flows and interflow zones at the site are relatively similar based on the results of extensive aquifer testing, whereas basalts and interflow units at the Monsanto site are indicated to differ substantially;
- Local water level elevation differences exist between adjacent upper basalt zone and lower basalt zone wells at Monsanto, in particular within the (UBZ/LBZ) 4 capture drawdown area of Monsanto's three largest production wells (Golder, 2012). Water quality and aquifer test data for the MST site indicate that the entire thickness of saturated basalt is in relatively good vertical hydraulic connection over the area of the MST site, and;
- Faults are considered to represent zones of increased transmissivity at the MST site. Within the Monsanto plant area, the Monsanto Fault and Subsidiary Fault are hinge faults that separate the upper basalt zone into distinct zones because of offsetting of permeable interflow zones against dense, low permeability flow interiors. The faults act as barriers to groundwater flow in the Plant area. South of the plant fence line, the offset on the faults decreases and appears to result in some hydraulic communication between UBZ regions (Golder, 2012).

2.1.3.1 Hydraulic Conductivities of the Basalt Aquifer

Primary permeability of unbroken basalt is small. Most ground water in the basalt aquifer is transmitted along secondary features such as joints or fractures. Vertical columnar joints are a common feature observed in basalt exposed to the south and southwest of the site along the trace of the Finch Spring Fault. The presence of intensely fractured or vesicular zones, rubble zones, and/or cinder zones can also greatly increase the ability of basalt to transmit water. Interflow zones are comprised of sub aerial deposited materials, including clays, cinderaceous deposits, alluvial sands and gravels, organic debris and weathered and broken basalt. Variations in the ability of interflow zones to transmit water result from changes in the character and thickness of these materials.

Observed hydraulic conductivities estimated from the slug, specific capacity, and pumping tests conducted in the shallow, intermediate-depth, and deep wells include the following:

- Basalts ranged from 8 to 340 ft/day;
- Interflow zones ranged from 90 to more than 200 ft/day.
- Basalts and interflow zones together ranged from 2 to more than 100 ft/day.
- Basalt No. Qb₅ (shallow basalt represented by shallow well screened zones) ranged from about 9 to 340 ft/day.
- Basalt No. Qb₃ (Deeper basalt screened in wells KM-10, KM-11, KM-12, and KM-18) ranged from 8 to almost 100 ft/day.

Hydraulic conductivities estimated for well KM-19 screened in Basalt No. Qb₂ and Interflow Zone No. I₁ ranged from about 15 to almost 70 ft/day. Results are presented in Table 1-1.

Generalizations about hydraulic conductivities observed within the basalt aquifer at the site include the following:

- The hydraulic conductivities of interflow zones are not significantly greater than those of the basalt flows;
- Hydraulic conductivities of the shallower basalts (Basalt No. Qb₅) are generally greater but not significantly greater than those of the deeper basalts (Basalt No. Qb₃);
- A horizontal layer of significantly smaller hydraulic conductivity which could greatly limit or prevent vertical movement of ground water was not identified;
- A continuous horizontal layer of significantly larger hydraulic conductivity along which horizontal ground water flow could be localized was not identified;
- Hydraulic conductivities in the shallow wells on the east side of the plant (KM-1, KM-2, KM-3, and KM-4) range from 90 to 270 ft/day and appear to be greater than hydraulic conductivities in shallow wells on the west side of the plant (KM-5, KM-8, KM-9, and KM-13), which range from 9 to 48 ft/day.

2.1.3.2 Estimated Ground Water Velocities

Horizontal hydraulic gradients within the shallower basalt aquifer vary from 0.01 feet per foot in the eastern part of the site to 0.03 feet per foot in the western part of the site. Effective porosities have been reported for the basalts of the Snake River Plain aquifer of southeastern Idaho to range from about 8 to 10 percent (Robertson, 1974; Lewis and Goldstein, 1982; Isherwood, 1981; Nace et al., 1959). If an effective porosity of 8 percent and range of hydraulic conductivities of 5 to 270 ft/day is used, then a range of estimated ground water particle velocities of 0.6 to 34 ft/day can be calculated for the eastern part of the plant site. The effective porosity of 8 percent and the observed range of hydraulic conductivities of 9 to 340 ft/day on the western of the site yield a range of estimated ground water particle velocities of 3 to 130 ft/day for the western part of the plant site, as shown in Table 1-1.

2.2 Current Direction and Rate of Ground Water Flow

Ground water flows in response to hydraulic gradients from areas of higher hydraulic head to areas of lower hydraulic head at rates that are proportional to hydraulic conductivity and hydraulic gradient and inversely proportional to effective porosity of the aquifer. Ground water can flow vertically through aquifers or between aquifers in response to vertical hydraulic gradients and horizontally within aquifers in response to horizontal gradients. Ground water in the Shallow Aquifer System generally flows southward from the topographically higher Blackfoot Reservoir (about 12 miles north of the MST site) to 5-Mile Meadows and to the Bear River, discharging along seeps and springs within the valley and along the topographically lower Bear River.

Horizontal hydraulic gradients and ground water flow directions within the shallow basalt are based on water level elevations measured during May and June 2012, incorporating 2012 data from the Evergreen site (City of Soda Springs, 2012) and from the Monsanto site (Golder Ass, 2012). Changes in water levels between May and June are assumed to be small based on known water level data. Water level elevations are contoured on

Figure 2-1. This figure shows the shallow water level elevations between the plant site and Big Spring. In 2012, the gradient between the calcine cap and well KM-9 on the plant site averaged about 0.02 ft/ft. The predominant flow direction beneath the plant site is to the west-southwest, as shown on Figure 2-1. The western ground water flow direction beneath the plant site is induced by pumping from the Monsanto production wells located west of the vanadium plant site. Ground water levels beneath the east side of the plant facility near the cap suggest a south-southwesterly flow from beneath the former scrubber pond and calcine cap. Ground water levels south of the cap and 10-acre pond are not known.

Figure 2-1 shows water levels west of the Finch Spring fault are substantially steeper than plant site gradients. Ground water gradients west of the Finch Spring fault range up to 0.08 ft/ft. The gradient begins to flatten to about 0.015 ft/ft between well TW-12 at the southeast corner of the Monsanto Plant site and well TW-67 located at the southern boundary of the Monsanto property. The water level map suggest that flow lines converge at, or near this location and the water level elevation in this well is only 15 feet higher than the elevation of discharge at Big Spring. Test results (Golder, 2012) indicate a very large hydraulic conductivity (from about 580 to 950 ft/day) for this well. The screened interval in well TW-67 is shown as highly permeable sand on the well log (Golder, 2012). Well TW-67 is located within the backfilled Little Spring Creek drainage. A small pond currently exists near the well. Little Spring Creek originally crossed the Monsanto Plant site, but no longer flows. This drainage was a topographic low-point for the property south of the Monsanto plant. Little Spring Creek was diverted through downtown Soda Springs in a series of constructed ditches, as indicated on older USGS maps (USGS, 1949), and shown on Figure 2-1. The USGS map indicates that this ditch was constructed from the TW-67 location to the Big Spring and the Soda Springs POTW areas, following lowest natural grade and along city streets. These ditches, like the Little Spring Creek drainage, were backfilled since the 1949 map and are removed from the newer USGS Soda Springs 7-1/2 minute topographic map. The ground water gradient under the town of Soda Springs between well TW-67 and Big Spring is very flat, averaging about 0.004 ft/ft.

2.3 Site Water Levels and Site Precipitation

Figure 2-2 presents annual rainfall totals for Soda Springs, Idaho between 1990 and 2012, obtained from Tigert Airport in Soda Springs. Figure 2-2 shows that the annual precipitation trend has been decreasing since 1990. Annual totals peaked at nearly 21 inches in 1993. Annual precipitation rates declined between 1997 and 2003 to about 11 inches. Annual precipitation rates increased on average between 2001 and 2005, to just over 15 inches on an annual average. Precipitation also averaged over 15 inches between 2008 and 2011. Precipitation was below average in 2012, and approximately 11 inches of moisture were recorded at the Tigert Airport in 2012. Five years in the past 22 years have recorded 11 inches or less annual total precipitation. Four of these drought events have occurred since 2001.

Figure 2-3a shows the ground water level elevations in the monitor wells. Water levels are notably seasonal. Water levels are typically higher by about 2 to 3 feet in the spring when compared with the fall water levels. In general, water levels show a decreasing trend between 1997 and 2004. The trend has been a very slight overall rise between 2005 and 2012. This trend is similar in the off-site wells over the evaluated period, as shown on Figure 2-3b. Overall, water levels dropped on average 5 to 8 feet between 1997 and October 2001, and then remained at lowered levels through 2004, as indicated on Figure 2-3a. Water levels recovered somewhat between 2004 and 2012 as a result of the increased annual moisture as shown on Figure 2-3a. A spike in water levels is noted in 2006. During 2011, the net seasonal change in water levels was smaller than previously observed seasonal differences.

Site ground water level changes over time correlate with variation in the annual average precipitation rates. Mean longer-term rising trends in site water levels lag the precipitation by about two to three years, based on the lowest observation of the mean moving average precipitation occurring in 2001 and the lowest mean water levels observed in 2004.

3.0 GROUND WATER SAMPLING

3.1 Ground Water Point of Compliance

The Record of Decision (EPA, September 1995) stated that the point of compliance (POC) for the evaluation of the selected remedial actions for ground water will be the boundary of the industrial plant facility, using the existing monitoring wells (EPA, 1995). During the RI, Kerr-McGee placed the existing monitor wells at strategic locations to monitor specific impoundments, aquifer units, downgradient off-site locations, and the facility as a whole. Locations of on- and off-site well placements and screen location depths are shown on Table 1-1 and were presented in previous technical memoranda and work plans.

During 2004, Kerr-McGee purchased the Hopkins property to the south of the former industrial facility. This property included the land containing the monitoring wells KM-15, KM-16, KM-17, and KM-18, that have been designated the “off-site” wells in all previous documents. The off-site designation throughout this document refers to these four wells that are located south of the industrial facility, as previously established.

POC wells include wells KM-2, KM-3, KM-5, KM-8, KM-9, KM-11, KM-12, KM-13, and KM-19. EPA requested the addition of wells KM-2, KM-3 and KM-11 to the list in their May 6, 1997 correspondence and Tronox included POC sampling for these wells. Table 3-1 provides the current justifications used for sampling of POC wells at the site, and for sampling off-site well and spring locations.

3.2 Ground Water Sampling and Analysis Plan

A ground and surface water sampling plan was developed for the RD/RA sampling events for on-going semiannual sampling. This plan was finalized and accepted by EPA in May 1997. An additional low-flow sampling plan was developed during September 1997 to incorporate low-flow sampling methods described below.

3.2.1 Low-Flow Purge Sampling Methods

Kerr-McGee and GET installed stainless steel submersible pumps in each of the sampling wells during October 1997. A pump was installed in KM-7 by GET during May 2000. These pumps are dedicated for evacuation and sampling purposes. Each pump is operated by a portable generator system. Each pump is suspended on Schedule 80 1-inch PVC piping and a stainless steel safety cable (in intermediate depth and deep wells), such that the intake level on each pump is placed in the approximate center of the well screened interval.

Low-flow well purging was first performed during the November 1997 sampling round following dedicated pump installation in each of the sampled wells. Low-flow sampling methods are based on EPA Region 1 “Low Flow SOP” dated May 13, 1996 and the EPA document “Low-Flow (Minimal Drawdown) Ground Water Sampling Procedures” dated April 1996. This method was provided as an addendum to the RD/RA Sampling and Analysis Plan (SAP) deliverable submitted to EPA during May 1997 and approved by Region 10 EPA on June 6, 1997. Low-flow sampling is performed on all of the “KM” series wells with the exception of non-POC wells KM-1 and KM-10. Wells KM-1 and KM-10 are monitored for water level purposes only, although these two wells were sampled in October 2008 and in May 2009 at the request of EPA.

During sampling, flow rates are measured concurrent with drawdown in each well to assess stabilization of purged ground water. A discharge assembly is used to control the rate of discharge from each well via use of a ball valve. The assembly is used to control discharge from each well during sampling such that the amount of discharge will not allow the well to be drawn down more than 0.3 feet during purging and sampling events.

Field measurements are made through the use of a turbidity meter and flow cell. The flow cell is used to measure pH, temperature, specific conductance, and dissolved oxygen. Field data are graphed following sample collection to show stabilization of field

parameter measurements with time prior to sample collection. These graphs are presented with the semiannual data validation reports. Criteria used to determine whether the purged water has stabilized include:

- pH within ± 0.3 units;
- Temperature to within ± 2 degrees;
- Specific Conductance within ± 10 percent;
- Dissolved oxygen within ± 10 percent, and;
- Turbidity within ± 10 percent.

If the parameters do not stabilize to meet the above criteria within the extraction of three casing volumes, then a sample is obtained following the removal of not more than three casing volumes. Samples are collected from the discharge point beyond the ball valve. Samples are collected and handled in accordance with the May 1997 SAP.

3.3 QA/QC Data Review

QA/QC review is performed on a semiannual basis after receipt of the data from the lab. Results of the QA/QC data reviews are presented in the semiannual data validation reports, and are not included in this annual ground water review.

4.0 GROUND AND SURFACE WATER QUALITY

The May 2012 round included the collection of samples between the dates of May 14 through May 16, 2012 the (May 2012 sampling round). The October 2012 round was completed between October 2 and October 4, 2012. Sampling of the Evergreen facility was completed for the City of Soda Springs on June 11, 2012. Sampling at Monsanto was from June 4 to June 14, 2012. Although the monitoring event at Evergreen and Monsanto followed the sampling at the vanadium plant site by about 4 weeks, interpretations that are made regarding the water levels and water quality between the sites are considered to be adequate to define the conditions for areas beyond MST property. The drawings note the differences in the monitoring events.

4.1 Background Water Quality and Type

Upgradient wells KM-1 and KM-10 were sampled during the RI, and again in the fall of 2008 and spring 2009 as part of the remedy evaluation. The results from 2009 sampling of these wells indicated that wells KM-1 and KM-10 contained vanadium and molybdenum at concentrations that were one to two orders of magnitude less than each respective RBC. Other locations sampled from historic background included Formation Spring, and several other private wells to the north and east of the site. These upgradient background locations have not been sampled since 1991 because site clean-up performance is based on the POC wells and background is considered to not contain the COC. The reader is encouraged to refer to the RI report (Dames & Moore, 1995) for information on these background sites.

TDS concentrations are expected to be about 500 mg/l in background wells and springs based on historic data. The largest reported TDS concentration from background locations was 579 mg/l in Formation Spring. The pH values measured at the background locations were near neutral and ranged from 6.8 to 7.4 units. Specific conductance ranged from about 840 umhos/cm in the private wells to about 970 umhos/cm in Formation Spring.

Reported background chloride concentrations were about 3.9 mg/l. Background sulfate concentrations are in the range of about 40 mg/l. Nitrate concentrations ranged from 0.11 mg/l in Formation Spring to 0.75 mg/l in private wells. Concentrations of aluminum, arsenic, chromium, manganese, molybdenum, nickel, selenium, and vanadium were less than detection at upgradient private wells and springs located to the east of the site.

Background ground water quality and type was characterized during the RI using the trilinear diagram classification method developed by Piper (1944). The Piper diagram consists of two ternary fields (triangles) for plotting percentages of cations (left triangle) and anions (right triangle), and a central diamond-shaped composite field for plotting the relative contribution of the major ion pairs. Based on the Piper plots, the site background water type plots in a specific pattern and can be classified as calcium-magnesium bicarbonate-type water.

4.2 Common Ion Distributions in Ground Water

The Piper plots evaluated during the RI indicated a mixing of background-type waters beneath the site with pond seepage and contributions from leachate produced by uncontrolled sources in the vadose zone. Ground water flowing onto the site is relatively high in calcium and low in sodium and potassium. Waters are also compositionally high in bicarbonate. Waters mixed beneath the site increase substantially in sodium, potassium, sulfate and chloride (Dames & Moore, 1995) from the effects of pond seepage.

4.3 General Ground Water Quality Parameters

4.3.1 pH

The pH range in wells across the site historically indicated neutral to slightly alkaline conditions in the past. Between 1999 and 2001, field pH was lower in many of the wells near the reclaimed S-X pond including samples from wells KM-6, KM-7, KM-8, KM-12,

KM-19, and near the reclaimed scrubber pond (KM-2, KM-3, KM-4, and KM-11). The lower ground water pH (range of 6.1 to 6.9) may have affected metals concentration trends during the 1999 through 2001 period, resulting in metals concentration increases during this period.

Site distribution of pH for May 2012 is shown on Figure 4-1. The pH is generally neutral across the site, decreasing slightly from west to east, with a larger pH around the former scrubber pond and lower pH around the south end of the former S-X pond. During the May 2012 sampling event, the lowest pH occurred in the vicinity of well KM-8.

4.3.2 Total Dissolved Solids

May 2012 concentrations of TDS for the plant area and the areas between the site and Evergreen are shown in Figure 4-2. May ground water TDS concentrations in the shallow aquifer ranged from 500 mg/l in well KM-13 to 9200 mg/l in well KM-8. The secondary drinking water standard for TDS (500 mg/l) was equal to, or exceeded in all but three of the POC wells. TDS is particularly elevated in shallow wells surrounding the southwest corner of the calcine cap or west of the covered scrubber pond. Concentrations of TDS in intermediate-depth well KM-11 (470 mg/l) is within the range of background. Beneath the west side of the site, TDS concentration in well KM-8 is substantially larger than nearby wells KM-9 and KM-13 which are close to background TDS concentrations. TDS is elevated above background in the plant areas between the scrubber pond and the S-X pond basin. TDS concentration in deep well KM-19 (460 mg/l) is within the assumed background concentration range.

At off-site ground water locations, TDS concentrations are slightly elevated in all wells at a level of about 100 mg/l above background extending to the Evergreen site. Finch Spring, located approximately 4400 feet south of the MST site, indicates a TDS concentration of 520 mg/l, while Big Spring indicates slightly larger concentration of 560 mg/l.

4.3.3 Turbidity

Turbidity was measured in the field during low-flow purging of the wells. Results of turbidity for the 2012 sampling events are summarized in Table 1 and presented graphically in Appendix A of the May 2012 Laboratory Data Quality Report (GET, July 27, 2012). Although turbidity is generally not considered an indicator of ground water contamination, excessive turbidity in an unfiltered sample can bias analytical results causing reported total metals concentrations to be unrepresentative of true concentrations in ground water (Dames & Moore, 1995). Turbidity is a measure of the solids and suspended organic material in a sample and is reported in nephelometric turbidity units (NTUs).

May 2012 turbidity ranged from 0.44 NTUs in well KM-13 to 15.5 NTUs in well KM-8. Well KM-8 frequently exhibited increased turbidity throughout its sampling history. Turbidity was reduced following re-development and removal of large amounts of sediment from this well in February 2000.

4.4 Selected Major Ions in Ground Water

4.4.1 Chloride

May 2012 concentrations of chloride are shown on Figure 4-3. The secondary drinking water standard for chloride is 250 mg/l. Chloride concentrations in shallow wells range from 18 mg/l in KM-9 to 1600 mg/l in well KM-8. Chloride was a predominant constituent in the S-X and scrubber ponds before these impoundments were removed from service between 1995 and 1997. May 2012 ground water chloride concentrations are elevated relative to background near the reclaimed scrubber pond as indicated on Figure 4-3. Wells KM-9 and KM-13 located to the southwest and west of the S-X pond, respectively have near-background chloride concentrations while nearby well KM-8 is two orders of magnitude larger in concentration. Concentrations of chloride in deeper wells, including

well KM-11 near the former scrubber pond and in wells KM-12 and KM-19 near the former S-X pond are smaller concentration and range from 10 to 35 mg/l. Chloride concentrations at Finch and Big Spring are 20 mg/l and 29 mg/l, respectively. Upper and Lower Ledger Spring chloride concentrations range from 5.5 to 5.9 mg/l and represent background levels.

4.4.2 Nitrate Plus Nitrite

Prior to the October 1995 sampling round, samples were analyzed for nitrate, nitrite, and nitrate plus nitrite. Results indicated that nitrite concentrations are relatively small in comparison with nitrate. Currently, only nitrate plus nitrite is analyzed. The primary drinking water standard of for nitrate is 10 mg/l. Nitrate plus nitrite concentrations at Upper and Lower Ledger Springs nitrate-nitrite range from 0.7 to 1.0 mg/l. While this may be representative of background concentration for the basalt aquifer, the nitrate trend at the Ledger Springs (city water supply) appears to be increasing with time.

Nitrate plus nitrite concentrations from the May 2012 sampling round are presented on Figure 4-4. The largest nitrate plus nitrite concentrations are centered about well KM-8 to the south of the covered S-X pond. However, larger nitrate concentrations are ubiquitous on the plant site, with larger concentrations issuing from the south west corner of the calcine cap near well KM-4. Nitrate plus nitrite concentrations are found in the ground water exceeding 10 mg/l beyond the industrial plant facility boundary to the south of well KM-8. Nitrate concentrations are elevated above 5 mg/l in a south-southwesterly direction extending to the Evergreen site. Nitrate plus nitrite is noted to be larger than background concentration at Finch Spring (3.0 mg/l) and at Big Spring (4.6 mg/l).

4.4.3 Sulfate

Sulfate demonstrates ground water distribution that is similar to chloride and TDS. Concentration distribution of sulfate in the aquifer is presented on Figure 4-5. Sulfate concentrations exceed background in an area that extends from the southern boundary

of the plant site to the Evergreen site. Reported concentrations of sulfate from the May 2012 sample round ranged from about 46 mg/l in well KM-5 to 6100 mg/l in well KM-8. Increased concentrations are centered immediately west and south of the covered scrubber pond and to the south and west of the covered S-X pond. Sulfate concentrations in the deeper wells are elevated with respect to background concentration, and range from 55 to 100 mg/l. The secondary drinking water standard for sulfate (250 mg/l) was exceeded in monitor wells KM-3 and KM-8. The largest sulfate concentrations in ground water are associated with areas infiltrated by the former S-X raffinate stream. The former S-X raffinate stream was routed to the site of the former scrubber pond during operations. Off-site concentrations of sulfate are elevated above background in wells KM-15 through well KM-18, ranging from 82 to 120 mg/l.

4.5 Selected Metals in Ground Water

4.5.1 Arsenic

Arsenic concentration in shallow ground water for May 2012 are summarized in Table 1-2 and are shown on Figure 4-6. Concentrations in the on-site wells range from 0.8 ug/l to 45 ug/l in well KM-8. Observation of arsenic in on-site wells indicates that arsenic is detected above or near the risk-based concentration of 10 ug/l in wells around the covered scrubber pond. Shallow wells KM-3 and KM-4 near the former scrubber pond exceeded 10 ug/l during the May 2012 sampling round.

Samples collected from off-site wells range from less than detection to 4 ug/l in well KM-16. Evergreen wells EV-1 and EV-2 (the most eastern wells) show elevated levels of arsenic reported at 14 ug/l and 9 ug/l, respectively. It is unclear that arsenic in the Evergreen wells originated from the vanadium plant site, but results from well EV-1 suggest increasing arsenic concentrations since 2008.

A review of arsenic concentrations in springs indicate Finch and Big Spring levels were small (0.54 ug/l to 0.33 ug/l), near the instrument detection limit for arsenic. Arsenic concentrations in Upper and Lower Ledger Springs were less than detection.

4.5.2 Manganese

Manganese concentrations are decreasing with time in nearly all of the wells. Manganese ground water concentrations in MST monitor wells are summarized in Table 1-2, and are shown on Figure 4-7. May 2012 manganese concentrations in shallow ground water for on-site wells ranged from 0.46 ug/l in well KM-5 to 6100 ug/l in well KM-8. The RBC for manganese (180 ug/l) was also exceeded in well KM-3 (510 ug/l) near the scrubber pond. Manganese also exceeds the RBC at a on-site well KM-6 (190 ug/l) in 2012.

Off-site manganese concentrations range from 6.6 to 95 ug/l. Wells EV-1 and EV-2 at Evergreen reported unusually large concentrations of manganese that do not correspond with previous results. Review of the data indicate that turbidities for the two wells range from 560 to 1150 NTU, much larger than the other two wells at the site. This large concentration of total suspended solids account for these large observed concentrations.

Very little manganese is noted in the springs in 2012. Manganese was less than the detection limit at Upper and Lower Ledger Spring. Manganese was 0.92 ug/l at Finch Spring and 0.62 ug/l at Big Springs in May 2012.

4.5.3 Molybdenum

Molybdenum concentrations from May 2012 are plotted on Figure 4-8. Molybdenum ground water concentrations from the May 2012 sampling round are summarized in Table 1-2. This table shows that all but two of the wells exceed the RBC for molybdenum. Molybdenum is also ubiquitous on site in ground water because molybdenum was a dominant metal in the S-X raffinate stream. It is therefore found in larger ground water concentration near the former pond source locations that received raffinate, as indicated

on Figure 4-8. During May 2012, on-site shallow well concentrations of molybdenum ranged between 180 ug/l in wells KM-5 and KM-13 to 36,000 ug/l in well KM-8. Figure 4-8 illustrates that concentrations of molybdenum are significantly elevated in areas centered to the south of the former S-X pond and to the south and west of the calcine cap and covered scrubber pond. . The molybdenum RBC is exceeded at all off-site MST well locations, and therefore, the eastern extent of impacted ground water exceeding the RBC (to the east of KM-17 and KM-2) is not known. Finch Spring and Big Spring initially fell below the molybdenum RBC in 2009 and remained close to or below the RBC through October 2012. Molybdenum was less than the detection in Lower Ledger Spring during May 2012, but was detected at 4.8 ug/l in Upper Ledger.

Figure 4-8a presents concentrations of molybdenum between the site and Big Spring incorporating 2012 data from the Evergreen Site (City of Soda Springs, 2012) and from the Monsanto site (Golder Ass, 2012). On the plant site, elevated molybdenum concentrations are shown to the south of the historic S-X pond and southwest of the historic scrubber pond. Concentrations of molybdenum are drawn to the west-southwest normal to water level contours. Elevated molybdenum concentrations are directed to the southwest along the upthrown block of the Finch Spring fault, then across the fault in a southerly direction towards well KM-15 and the Evergreen wells. From this point, the Monsanto wells and the Lewis well define a distinct western boundary to the molybdenum plume from the vanadium plant. The eastern boundary of the plume is not well defined between Finch Spring and Big Spring.

Monsanto well TW-67 is the furthest well location from the plant site that exceeds the RBC for molybdenum in ground water. The screened interval in well TW-67 is within highly permeable sand. Test results (Golder, 2012) indicate a very large hydraulic conductivity for this well. Well TW-67 is located within the backfilled Little Spring Creek drainage. Little Spring Creek no longer flows, but at one time was diverted through town in a series of constructed ditches, as indicated on older USGS maps (USGS, 1949). The USGS map indicates that this ditch was constructed from the TW-67 location close to Big Spring and the Soda Springs POTW. These ditches, like Little Spring Creek, were backfilled.

4.5.4 Vanadium

Ground water vanadium concentrations in the MST monitor wells in October 2012 are plotted on Figure 4-9 from the May 2012 sampling round. Vanadium was a dominant metal in the S-X raffinate stream. Vanadium is detected at concentrations above the RBC (260 ug/l) in all of the on-site wells with the exceptions of intermediate well KM-11 and deep well KM-19. May 2012 vanadium concentrations in the ground water ranged between 8.4 ug/l in KM-11 to 13,000 ug/l in well KM-8. Figure 4-9 illustrates that vanadium has a similar distribution trend to nitrate in ground water, with the larger concentrations identified between well KM-4 near the south west corner of the calcine cap to well KM-8 to the south of the former S-X pond location.

Vanadium concentrations in off-site monitor wells located southwest of the site all exceed the vanadium RBC with the exception of well KM-17 (14 ug/l) that remains substantially below the RBC for vanadium. Similar to the off-site flow of molybdenum, large concentrations of vanadium are noted in the ground water in a zone that extends south of the S-X pond basin, extending to the south along or near the Finch Spring fault to the Evergreen site. All four wells at the Evergreen site exceeded the RBC for vanadium in 2012.

Figure 4-9a shows concentration distribution of vanadium between the site and Big Spring, integrating 2012 data from the Evergreen Site (City of Soda Springs, 2012) and from the Monsanto site (Golder Ass, 2012). On the plant site, elevated vanadium concentrations are shown to the south of the historic S-X pond and from the southwest side of the calcine cap. Concentrations of vanadium migrate to the west normal to water level contours. Elevated vanadium concentrations are directed to the southwest along the upthrown block of the Finch Spring fault close to KM-16, then across the fault in a southerly direction towards well KM-15 and the Evergreen wells and Monsanto well TW-12. From this point, the Monsanto wells and the Lewis well define a distinct western boundary to the vanadium plume from the vanadium plant. The eastern boundary of the plume is not well defined, but

likely exists between Finch Spring and Evergreen. The eastern boundary between Finch Spring and Big Spring is not known. During May 2012, the vanadium concentration in Finch Spring was elevated (49 ug/l), but much smaller (3.4 ug/l) at Big Spring. Vanadium was reported at 1.9 ug/l in Upper Ledger Springs and 1.2 ug/l in Lower Ledger Springs.

Monsanto well TW-67 is the furthest well location from the plant site that exceeds the RBC for molybdenum. Elevated vanadium concentrations are also observed in this well (229 ug/l in May 2012). The vanadium off-site plume is similar to the distribution of molybdenum, but no information is known for vanadium concentrations in the area between TW-67 and Big Spring. Big Spring discharges elevated but decreasing concentrations of molybdenum over time. Vanadium concentrations over time at Big Spring remain small.

4.6 Organic Compounds in Ground Water

As noted during the RI (Dames & Moore, 1995), COC semi-volatile organic compounds that include tributyl phosphate (TBP) and total petroleum hydrocarbons (TPH) originated from the No. 1 fuel oil carrier used in the solvent extraction (S-X) process and found in the S-X raffinate stream. These compounds were detected in the former ponds and in the ground water. POC wells were sampled for total petroleum hydrocarbons and for semi volatile compounds for the detection of TBP through 1999. Organics were sampled in all POC wells in May/June 2002 as requested by EPA for evaluation in the 5-year review. Organics are not sampled at off-site locations. Currently, only well KM-8 is sampled for organics.

4.6.1 Total Petroleum Hydrocarbons

TPH provides screening level estimates of total organic compound concentrations within certain hydrocarbon ranges but does not identify or provide concentrations of specific organic compounds. TPH was analyzed using Method 418.1 through 1999. This method could no longer be used because Freon was discontinued for use in the method by federal

regulation. During the May 2012 sampling round, TPH was analyzed using Method SW846 8015B that included analysis for a range of C₁₀ through C₃₆. TPH concentrations in POC monitor well KM-8 during 2012 ranged from 13 to 1.4 mg/l, greater than the RBC (0.73 mg/l).

4.6.2 Tributyl Phosphate

TBP was used in the S-X raffinate stream and was detected at concentrations above the RBC (180 ug/l) in the wells near the reclaimed S-X and scrubber ponds during 1997. Results of previous analyses in off-site wells suggest that TBP does not exceed the RBC downgradient of the plant facility boundary. During a number of sampling past events, TBP was not detected. During 1999, TBP was detected only in well KM-8 at 1400 ug/l. During 2000 and 2001, TBP was not detected in well KM-8. It is probable that some of the unknown compounds in KM-8 may be the result of degradation of the TBP compound. In 2012, TBP concentrations ranged from 280 ug/l to 450 ug/l in well KM-8, greater than the RBC.

5.0 CONCENTRATION TRENDS WITH TIME

5.1 General

Plots of concentration versus time are shown on the graphs presented in Appendix A. These graphs of routinely sampled well and spring sites present common ion and general indicator trends, including chloride, nitrate plus nitrite, sulfate, and total dissolved solids. Metals concentration graphs include COC parameters arsenic, manganese, molybdenum, and vanadium. During 2012, charted organic parameters include TBP and TPH from well KM-8 only because other wells were not sampled for organics.

The charts in Appendix A are annotated, where appropriate, to show periods of pond operation, the approximate time that liquid source elimination (LSE) was implemented as a remedial action, and the time that calcine capping was performed. Observed increases and decreases in ground water concentrations shown on the plots result from:

- Process changes during plant and pond operation;
- Liquid source elimination (LSE), removal of pond sediments and pond reclamation that resulted in decreased concentrations;
- Changes in ground water pH;
- Changes in annual precipitation, water ground water levels, and subsequent gradients;
- Advective transport, matrix diffusion and natural attenuation in the aquifer.

Table 5-1 provides a chronology of process and site reclamation events, pond management events and other site events to provide some understanding of how process or other changes on site may have affected changes to ground water concentrations over time. A number of these measures have resulted in increasing and decreasing concentrations in the wells, as well as short-term concentration increases for a few of the COCs following implementation of the site remedy.

5.1.1 Fate and Transport of Graphed Chemical Parameters

Inorganic constituents evaluated versus time include metals and common ions. Constituents can be non-reactive and move through the ground water, unaffected by biotic (metabolism, such as microorganisms) and abiotic (adsorption, ion exchange, precipitation, hydrolysis, redox) processes. The fate of specific compounds ultimately depends on the reactivity or non-reactivity of the chemical with the media during transport.

Common Ions

Graphs of the non-reactive chemicals include chloride, a member of the halogen group that is one of the most commonly detected anions in natural water. The transport of chloride through the ground water is largely through physical (hydrodynamic) processes. Chlorides travel at essentially the same rate as the ground water (Knox et al., 1993); the graphs indicate that chloride concentrations changed quickly in response to modifications in plant and pond operations, LSE and subsequent reclamation efforts.

Chloride ions can form complexes with a few of the positively charged ionic species, however, these complexes are usually weak, and are generally considered insignificant unless chloride concentrations are very large (Hem, 1978). Chloride is considered one of the best tracer elements, and is widely used experimentally in tracer models. In general, chloride does not enter into reduction/oxidation (redox) reactions, does not form solute complexes with other ions, does not adsorb to mineral surfaces and does not form salts of low solubility.

In the absence of plant growth, nitrate behaves as a mobile anion, similar to chloride (Drever, 1988). Nitrate concentrations can be rapidly reduced in surface waters through assimilation by aquatic plants (National Academy of Sciences, 1977). Attenuating factors

for nitrates do not appear significant at the site, and concentrations may be reduced primarily through dilution in the aquifer.

The sulfate ion is chemically stable, and forms salts of low solubility with only a few metals (Hem, 1978). Once sulfate has dissolved in water, it generally remains in solution except where it is anaerobically reduced to sulfide, precipitated in sediment, released to the atmosphere, or incorporated into living organic matter.

Metals

Several processes interact to control the reactivity and rate of transport of compounds in ground water. Metal ions can be strongly adsorbed to mineral surfaces in a porous medium (such as a clayey interflow zone in a basalt sequence), or to rock surfaces exposed by fractures. Effectively, this would inhibit metal transport through the aquifer when complexed with other ions. Some metals can be transported at average velocities that are orders of magnitude faster than when not complexed because of changes in the attenuation properties for the complexed metal.

Changes in metal speciation and reactivity within the matrix of the aquifer can result from encountering different chemistries within the aquifer. The mobilities of different oxidation states of metals such as arsenic, manganese, molybdenum, and vanadium may also differ by orders of magnitude (Allen et al., 1993).

In solution at neutral pH, the stable forms of arsenic would be arsenate oxyanions (Hem, 1978), with the dominant form being dependant on the pH of the water. Inorganic factors that maintain low concentrations of arsenic in water include adsorption by hydrous iron oxide, co-precipitation or combination with sulfide.

The transport and partitioning of manganese in water is controlled by the solubility of the specific chemical form of manganese that is present (USHHS, 1990). The solubility and speciation of manganese oxides in solution is largely a function of pH and redox potential.

Manganese can also be subject to microbial activity. The principal anion associated with manganese is carbonate, although in waters with large bicarbonate concentrations, manganese bicarbonate complexes can be formed. In waters containing an excess of 1000 mg/l sulfate, manganese sulfate may become the dominant species. In extremely reduced water, the fate of manganese tends to be controlled by the formation of poorly soluble sulfide (USHHS, 1990). The tendency for soluble manganese to adsorb to soils and sediments depends largely on the cation exchange capacity and the organic composition of the soil (USHHS, 1990). Soil adsorption for manganese may be significant in the soils at the site, can be highly variable and can span five orders of magnitude, increasing as a function of organic content and ionic exchange capacity with the soil (Baes and Sharp, 1983). At small concentrations, manganese may become fixed by clays, whereas, at larger concentrations manganese may be desorbed by ion exchange with other ions in solution (USHHS, 1990).

Molybdenum is readily soluble in water, and is likely to be more mobile than metal cations in the ground water. Multiple valence states are a complicating factor in molybdenum chemistry. The anionic (molybdate) species are probably predominant in natural water (Hem, 1978).

Vanadium can exist in ground water systems in multiple valence states, but predominantly in two forms or oxidation states. One of these vanadium forms is highly mobile and chemically reactive and is identified as the vanadate (vanadium⁺⁵) or pentavalent state for vanadium. This is the most common oxidation state for vanadium in ground water systems and results from high temperature oxidation, such as that which occurred to the soluble vanadium ore in the plant roasters. A second and a highly immobile state of vanadium is vanadium ⁺⁴ state. Both species are closely connected to the oxidation state (Tracey, 2007) of vanadium and pH. Vanadium⁺⁵ can be complexed by components in sediments and subjected to a reducing environment where conversion to (V⁺⁴) results, and vanadium will remain immobile unless it is disturbed (Tracey, 2007).

Transport of vanadium in water and soil is influenced by redox potential, pH, and the presence of particulate (USHHS, 1990). Vanadium species have a tendency to bind strongly to mineral or biogenic surfaces by adsorption or complexing; hence it can be transported either in solution or in suspension. Adsorption may be a significant attenuating factor at the site, but oxidation state plays an important role. Advective transport, adsorption, matrix diffusion, chemical sorption reactions with mineral surfaces and natural attenuation may also play central roles in the movement (or non-movement) of vanadium in the basalt aquifer.

5.2 Trends for On-site and Point of Compliance Wells

5.2.1 Common Ions and General Indicators

Parameters including TDS, sulfate, and chloride indicate similar decreasing trends at the on-site non-compliance and POC wells. The pH is also a general indicator that may have affected historic metals trends and concentrations at some locations. Based on a review of concentrations versus time for these parameters, the following general observations are presented.

pH

Ground water in the vicinity of the reclaimed scrubber pond had neutral to slightly alkaline pH values through early 1999, relatively unaffected by process waters during plant operation or LSE. Following the summer of 1999, a general decrease in pH was noted in the shallow ground water through 2001 and in a few wells in 2002. The pH rose in these wells following 2002 to the neutral range in 2003. Trends between 2003 and the present indicate the ground water beneath the site is in the near-neutral range, with lowered pH in the ground water near well KM-8. The site pH trend noted in 2012 was generally neutral to slightly basic across the site, with generally decreasing pH from east to west. The lowest pH range continues to remain to the south of the former S-X pond.

TDS

TDS concentration trends for ground water in wells located near the former site ponds and facilities are contained in Appendix A. Wells located near the east scrubber pond indicate an increase in TDS concentrations through 1995. Generally decreasing concentrations are indicated following LSE, with a flattening but decreasing trend between 2000 and the present. The TDS ground water concentrations for May 2012 are shown on Figure 4-2.

During vanadium plant operation, increases in TDS concentrations (between 1993 and 1995) are attributed to the diverted discharge of the S-X stream into the scrubber pond instead of discharging to the S-X pond. During 1997, the scrubber pond liquid was pumped to the calcine pond in preparation of the scheduled remedial action for this facility. Incidental residual liquid in the scrubber pond was released from the pond near the location of well KM-3 during the stabilization of the scrubber pond solids. As a result, well KM-3 TDS concentrations spiked during 1997 from the effects of the residual liquid ponding at the surface in the near vicinity of the well. TDS concentrations in well KM-3 have been decreasing since November 1997 following pond closure and reclamation.

Shallow wells near the former scrubber pond demonstrated larger variability in TDS concentrations between sampling events prior to pond closure. All wells continue to indicate overall decreasing trends, although concentrations spiked in May 2006 and decreased to the present range of concentration. TDS ground water concentrations in well KM-3 appear to show greater seasonal variability between 2000 and the present, compared with other shallow wells in this area. Seasonal increasing/decreasing trends may account for some of the variability between rounds. Intermediate depth well KM-11 demonstrates comparatively little variability.

Wells KM-5 near the historic scrubber pond located west of the plant and wells KM-9, KM-12, and KM-13 located near the west side of the facility or near the reclaimed S-X pond indicate a general TDS concentration decrease with time, and smaller overall decreases following 2000 as concentrations approached background. Concentrations of TDS in these wells have remained relatively range-bound since 2007. A spike in concentration is noted in 2006, with a smaller spike in 2011, both spikes corresponding with increased annual moisture (Figure 2-2). Well KM-6 indicated slightly increasing concentrations through 1999, followed by a decreasing TDS trend through 2002 and a flattening of the trend between 2001 and the present. A spike in concentration is noted in the spring of 2006 and again in 2011. Deep well KM-19 is near background concentration with respect to TDS. Well KM-8 indicates substantial variability with time, and suggests an overall decreasing trend between 1995 and 2005. TDS is variable in well KM-8 ground water after 2005, but TDS has a range-bound or slightly increasing trend between 2005 and 2012. Seasonal increasing/decreasing trends account for some of the variability between rounds.

Chloride

Chloride concentrations have decreased from the early 1990's to the present levels noted on Figure 4-3. Chloride concentration trends in ground water for wells located near the former pond facilities are contained in Appendix A. Trend graphs in Appendix A show that ground water in the vicinity of the reclaimed scrubber pond increased in chloride concentration through 1995 as a result of S-X stream discharges to this location. During 2012, chloride concentrations were substantially greater near the scrubber pond and in well KM-8 near the former S-X pond. Shallow wells near the scrubber pond display variable chloride concentrations through 1997 between sampling events as the result of seepage from unlined pond operations. Intermediate depth well KM-11 was less affected by pond operational changes and indicates a more even (smoother) chloride trend with time. All wells monitoring ground water in this area demonstrate decreases in chloride concentrations between November 1997 and the present. The decreasing chloride trend in KM-2 slowed considerably after 2003, but

chloride continues to decrease to the present at nearly all locations. Chloride concentration trends are nearly identical to TDS trends.

Wells located near the west side of the facility or near the former reclaimed S-X pond indicate chloride concentration decreases with time, with a general flattening of the trends between 2001 and the present. Well KM-6 chloride concentrations are also decreasing, but remain elevated above other wells in this area. A number of wells demonstrated an increase in concentration during the spring of 2006. Well KM-8 chloride concentrations show seasonal variability with larger concentrations in the fall, but generally decreasing concentrations through 2000, followed by a lack of seasonality in the data through 2004. Concentrations of chloride in well KM-8 between 2005 and 2012 suggest a range-bound trend.

Sulfate

The May 2012 distribution of sulfate in ground water on site is shown on Figure 4-5. Sulfate concentration trends for wells located near the former pond facilities are contained in Appendix A. Sulfate trends in ground water near the reclaimed scrubber pond exhibit decreasing concentration trends that are comparable to chloride. An increase is noted in sulfate concentrations through 1996 as a result of S-X stream discharges to this location. Sulfate concentration increases in well KM-3 in 1997 resulted from incidental residual liquid in the scrubber pond that was released from the pond during remediation and reclamation activities. As the direct result, concentrations of sulfate in well KM-3 spiked during 1997. KM-3 sulfate concentrations have decreased steadily since that time. Sulfate concentrations in wells KM-2 and KM-11 have been steadily decreasing between 1999 and the present. Sulfate concentrations in well KM-4 indicate decreasing concentration trends since 1997. Well KM-11 was less affected by pond operations and shows an even (smoother) trend with time and a longer duration of peak sulfate concentrations. Sulfate concentration decreases near the scrubber pond have slowed between 2007 and the present.

Wells KM-5, KM-9, KM-12, and KM-13 sited near the west side of the facility or near the former S-X pond demonstrate sulfate concentration decreases over time with a flattening of the trend after 2000. Well KM-19 sulfate concentrations decreased to near background concentrations in 1998. Well KM-6 indicated little change with time through 2000, and then began to decrease though the present level, with a small spike noted in the spring of 2006. Sulfate concentration decreases near the S-X pond have slowed between 2007 and the present. Well KM-8 sulfate concentrations show similarities to chloride and TDS trends. Well KM-8 sulfate continued to indicate decreasing trends between 1995 and 2005. Concentrations are noted to be seasonal but relatively range-bound since 2005. Less seasonal variability in concentration is noted between 1999 and 2004, with more variability noted between 2004 and the present. Increased concentrations were noted in the fall during periods of lower water level elevations in this well prior to 2005. Since 2005, larger sulfate concentrations in well KM-8 typically (but not always) occur during the spring sampling round.

Nitrate plus Nitrite

Nitrate plus nitrite concentration trends for wells located near the former pond facilities are contained in Appendix A. Wells KM-3 and KM-11 located near the reclaimed scrubber pond have relatively small nitrate plus nitrite ground water concentrations and trends with a relatively flat trend since LSE was implemented. Well KM-2 initially shows relatively larger nitrate plus nitrite ground water concentrations, with declining concentrations between 1999 and 2003, followed by a flattening trend and a spike in concentration occurring in 2006. Following LSE, a decreasing nitrate trend was noted in well KM-4. However, well KM-4 nitrate plus nitrite concentrations indicated an increasing concentration trend beginning in the fall of 2001 through the present, with significant spikes in concentration occurring 2005 to 2006, in 2009 and in 2011. The 2005 to 2012 nitrate plus nitrite ground water concentrations in well KM-4 are comparable to concentrations noted during the period when the scrubber pond and calcine ponds were operational.

Shallow wells near the west side of the facility or near the former S-X pond indicated a spike in nitrate plus nitrite concentration between 1993 and 1994 and variable concentrations with time during plant operation. Most wells show decreasing nitrate plus nitrite concentration between 1997 through May 2000. However, since 2001, a number of these wells show increasing concentration trends, with spikes in 2006, 2009 and 2011. Concentrations in well KM-6 suggest a steadily increasing trend between 2001 to the present, with notable spikes in 2006 and in 2011. Nitrate plus nitrite ground water concentrations in well KM-7 have been increasing since 2001 and are the most variable of this group of wells. KM-7 nitrate concentration levels in 2011 exceeded levels noted during plant operations. Wells KM-13 and KM-9 also suggest slightly increasing nitrate concentration since 2004. Deeper wells KM-12 and KM-19 indicate little change with time. Well KM-8 concentrations spiked in 1994 and 1997, and decreased through 2001 following LSE. After 2001, an increasing nitrate plus nitrite concentration trend is noted in KM-8.

5.2.2 Metals Concentration Trends

Graphs of metal concentrations versus time include the group of metals identified by EPA as COC. COC metals versus time are presented in Appendix A and described in the following sections.

Arsenic

The arsenic risk based concentration (RBC) is 10 ug/l. This concentration value is based on the Federal MCL for drinking water. The results from May 2012 indicate that wells KM-3, KM-4 and KM-8 exceeded the drinking water standard for arsenic, as shown on Figure 4-6.

Arsenic versus time plots presented in Appendix A indicate that wells located near the former scrubber pond denote ground water arsenic concentrations that are fairly consistently within the range of the RBC (10 ug/l). Well KM-3 demonstrates a slight increase in arsenic through 1997, primarily during the time-period that the S-X stream

was diverted to the scrubber pond. Well KM-2 spiked in 1994 and decreased since that time. Well KM-4 spiked in 1994 and again during 1997. Concentration spikes may have been related to discharge of the S-X stream to the scrubber pond. Arsenic concentrations have generally been decreasing near the former scrubber pond since LSE and reclamation in 1997, with a flattening of the trend since 1999.

Wells near the west side of the facility or near the former S-X pond indicate an arsenic concentration decrease with time through 1995. Sample results since October 2007 indicate that the 5 ug/l detection limit did not result in an increased number of wells exceeding the arsenic RBC. Arsenic concentrations in 2012 are smaller than those levels noted in 1998 for these wells.

Well KM-8 indicated an increasing trend following May 1995 when the pond was taken out of service, with a peak concentration occurring during 2002. The cause for the increase in arsenic concentrations since closure of the S-X pond is unknown. Concentrations of arsenic decreased between 2002 and May 2006. Concentrations increased again between 2006 and 2008, then decreased between 2008 and May 2012.

Manganese

Ground water manganese concentration trends in wells located near the former pond facilities are contained in Appendix A. Wells located near the former scrubber pond show uneven manganese concentrations throughout operation and then small decreases to the present. Increases in the concentrations of manganese during earlier time periods are attributed to S-X stream discharge into the scrubber pond. Wells KM-3 and KM-4 show significant variability between sample rounds through 1997. Manganese concentrations in well KM-4 ground water spiked during 1994 and decreased through the present. Manganese concentrations in well KM-3 spiked during 1997, decreased with time through 2000, then demonstrated a steady increasing trend

through 2011. Well KM-3 is the only well near the scrubber pond that currently exceeds the RBC for manganese.

Wells near the west side of the facility or near the former S-X pond indicated a decrease in manganese with time between 1995 and 2000. Trends for manganese have flattened from 2000 to the present. Wells KM-6 and KM-7 indicate considerable manganese concentration variability with time that suggests seasonal trends, although this was less notable between 2002 and 2004. KM-6 indicated a relatively range-bound trend between 2004 the present, with spiking manganese concentrations in 2006, 2009 and 2011 to 2012. Deep well KM-19 ground water is at background concentration levels.

Manganese concentrations in well KM-8 continue to exceed the RBC by an order of magnitude. During plant operation, manganese trends in well KM-8 showed decreasing concentration through 1994, followed by increasing concentrations through 1997. Concentrations of manganese fluctuated, but generally began to decrease several years following LSE and reclamation efforts in 1997. Following 2004, manganese concentrations in well KM-8 began rising with wide variability through 2012. Larger and increasing seasonal variability is noted between 2004 and 2012. Concentrations of manganese are currently within the range noted during pond operation.

Molybdenum

Ground water molybdenum concentration trends in wells located near the former pond facilities are contained in Appendix A. Molybdenum trends with time are comparable to sulfate trends. Both are mobile anions in ground water.

Wells located near the former scrubber pond show decreasing molybdenum concentrations with time following LSE and reclamation. This decreasing rate has slowed substantially in wells KM-2 and KM-3. Molybdenum concentrations in well KM-3 spiked in 1997 during the remediation and stabilization of the scrubber pond solids.

Well KM-3 molybdenum concentrations increased between 2000 and 2003, then declined slightly to the present levels.

Wells KM-5, KM-9, KM-12, KM-13, and KM-19 located near the west side of the facility or near the reclaimed S-X pond indicated a concentration decrease with time through 2000, with much smaller decreasing trends noted between 2000 and the present. Concentration trends have essentially flattened since 2007. Well KM-6 indicates an overall decreasing molybdenum trend through 2003, with a range-bound trend between 2003 and 2012. Molybdenum spikes occur in 2006, 2009 and 2011. Larger molybdenum concentrations are typically noted during the spring sampling event.

Molybdenum concentrations in well KM-8 peaked during late 1994. Well KM-8 indicates substantial concentration variability with time similar to the common ion trends and an overall decreasing concentration trend with time following LSE. This decrease continued through 2005. Since 2005, concentrations of molybdenum appear seasonal but range-bound at concentrations that are two (2) orders of magnitude greater the RBC.

Vanadium

Vanadium ground water concentration trends in wells located near the former pond facilities are included in Appendix A. Shallow wells located near the reclaimed scrubber pond indicate decreasing vanadium concentrations for most wells with time following LSE in 1997, but all wells indicate vanadium concentrations that are essentially range-bound after 2005.

Well KM-11 ground water vanadium concentrations are an order of magnitude below the RBC, and demonstrate little change since 1997. Well KM-3 trend indicates a flattening of the vanadium concentration between May 1998 and May 2001 and a steady trend in concentration of vanadium to the present. Vanadium concentrations in well KM-3 have been seasonal but have not substantially decreased since 2005. Well

KM-4 vanadium concentrations increased substantially through 1997 and decreased with time through 2004. Concentrations of vanadium in ground water from well KM-4 have been highly variable but range-bound since 2004. Well KM-2 vanadium concentrations increased through 1996 as the result of the S-X discharge to the scrubber pond, and decreased substantially in 1997 when the pond was reclaimed and the calcine pond dried. The trend for vanadium concentrations in well KM-2 ground water have been within a narrow range since 2005.

Well KM-5 located near an historic scrubber pond and wells KM-6, KM-7, KM-9, KM-12, KM-13, and KM-19 located near the west side of the plant facility and near the reclaimed S-X pond indicate that vanadium concentrations decreased more quickly with time prior to 2001. Wells KM-9, KM-12, KM-13, and KM-19 continue to decline in concentration to the present at a slower rate since 2001. Wells KM-5, KM-6 and KM-7 declined in concentration through 2004; however concentrations of vanadium in these wells have generally been range-bound since 2004. Wells KM-5, KM-6 and KM-7 ground water vanadium concentrations spiked in 2006, 2009 and in 2011, corresponding with periods of increased annual moisture (Figure 2-2).

Well KM-8 vanadium concentrations are highly variable, but began to decrease in 1992 (during plant operations) and continued to decrease following LSE in 1997. In May 1998, vanadium concentrations began to increase substantially in well KM-8 with an increasing trend through 2004. Vanadium concentrations in well KM-8 ground water have been generally decreasing since 2005, but concentrations continued to be highly variable between 2005 and the present.

5.2.3 Organics

Total Petroleum Hydrocarbons

KM-8 is the only POC well routinely sampled for TPH. TPH concentrations with time for well KM-8 are contained in Appendix A. Concentrations of TPH decreased with time in

well KM-8 to less than detection in 1999. During 2000 and 2001, TPH ground water concentrations increased above historic ranges. Concentrations have decreased since 2000 to current levels of about 1.4 mg/l. The TPH ground water concentration trend in this well shows a substantial decrease between 2000 and 2005, with relatively steady concentrations since 2005 demonstrating seasonal trends.

Tributyl Phosphate

KM-8 is the only POC well that is routinely sampled for phosphoric acid tributyl ester (TBP). Well KM-8 TBP concentrations with time are charted in Appendix A. Concentrations of TBP decreased through 2005 in well KM-8. Concentrations appear seasonal, with larger concentrations generally noted in the spring sampling events. Concentrations have been within the same seasonal range since 2004, with spikes occurring in 2008 and 2011.

5.2.4 Conclusions of On-Site Well Concentration Trends

Conclusions drawn from the review of on-site well concentration trends include:

- Nearly all on-site wells continue to exceed the RBC for molybdenum and vanadium.
- Molybdenum and vanadium has flattened or become range-bound for most of the on-site wells for the past five (5) to seven (7) years.
- Nitrate concentrations began to increase at many of the on-site locations after 2001. The location source for this nitrate is not well-understood.
- Some concentration spikes have been observed for nitrate, molybdenum and vanadium since remedy completion. This occurrence is notable in wells located along the southern boundary of the plant facility. Spikes are most notable in 2006, 2009 and 2011, years that correspond with increased annual moisture.
- Ground water in well KM-8 trends somewhat differently from the other site wells. Vanadium concentration increased three-fold following remedy completion through 2004. Vanadium concentrations in well KM-8 have fallen since 2004 to current levels that are within in the range of vanadium noted in ground water during plant operation.

- Concentrations of common ions generally decreased through 2012 in almost all POC wells following LSE and surface reclamation with larger concentrations in areas near or immediately downgradient of the former S-X pond and scrubber ponds.
- Concentrations of manganese declined following LSE to less than the RBC in all on-site wells with the exception of KM-6 and wells KM-3 and KM-8 that demonstrate increasing concentration trends over time.
- TPH continues to slightly exceed the RBC in KM-8, although trends indicate a relatively flat but seasonal trend.
- TBP is currently detected in KM-8 within the same concentration range noted for the past ten (10) years. TBP is seasonal and occasionally has not been reported.
- Arsenic remains above the arsenic MCL in well KM-8 near the covered S-X pond, but arsenic concentrations have been generally decreasing since 2002. Arsenic also exceeds the MCL in wells KM-3 and KM-4.

5.3 Off-Site Well Concentration Trends

The following sections provide a discussion of concentration trends with time for the off-site wells (MST wells located beyond the POC), located to the south of the plant facility on the property previously owned by Larry Hopkins, but purchased by Kerr-McGee in 2004 and transferred to the MST in February 2011. Off-site wells that are now on MST property include wells KM-15, KM-16, KM-17, and intermediate depth well KM-18. Changes in concentration with time are generally smaller in the off-site wells as a function of their greater distance from the site and pond areas that impacted ground water quality. The COC concentrations in the Evergreen wells are also evaluated in this section in conjunction with the off-site wells.

In general, concentrations and concentration trends observed in paired shallow and intermediate wells KM-15 and KM-18 are similar for some of the monitored parameters as the result of the downward vertical gradient noted between water levels in these wells. Concentrations decreased steadily in these wells since the time of the remediation of the MAP ponds in 1993. Wells KM-15 and KM-18 appear to be more directly affected by activities on the west side of the plant facility. Well KM-16 indicates

seasonal fluctuations and spikes in concentrations for several constituents, in particular during 2006 and 2011. Well KM-16 also demonstrates similar concentration trends to on-site well KM-6. Well KM-17 has been impacted by operations on the east side of the site that occurred in the vicinity of the former scrubber pond. Well KM-17 has relatively large concentrations of common ions and molybdenum, but appears minimally impacted by arsenic, manganese, and vanadium.

5.3.1 Common Ions and General Indicators

Based on a review of concentrations versus time for these parameters, the following general observations are described below. Graphs of concentrations versus time that are the basis for identifying the trends are contained in Appendix A.

TDS

Paired wells KM-15 and KM-18 have similar TDS concentrations, and show an overall decrease in concentration with time through 2012, with a flattening of the trend after 2005. Well KM-16 shows a decreasing trend with time following LSE, but also demonstrated a spike in concentration in 2006 and in 2011. Seasonal trends account for some of the variability between rounds. Increased concentrations in well KM-16 occurred during periods of increased moisture and higher water level elevation.

Chloride

Wells KM-15 and KM-18 indicate matching concentrations, and show an overall decrease with time, beginning prior to LSE. The trend flattened between 2003 and the present. Concentrations of chloride in wells KM-16 and KM-17 lag wells KM-15 and KM-18 and were directly affected by LSE, since wells KM-15 and KM-18 indicated an earlier decrease in chloride. KM-16 indicated a larger decrease following 1999. Well

KM-17 chloride concentrations were the largest identified in the off-site wells through 2005. Concentrations are currently similar and have been range-bound since 2007.

Sulfate

Ground water in wells KM-15 and KM-18 indicate nearly identical sulfate concentrations, and show an overall decrease with time since initial sampling in 1992. This trend flattened after 2000. Well KM-17 sulfate concentration trends decreased following LSE and scrubber pond reclamation efforts in 1997. Sulfate concentrations have been range-bound in all of the off-site wells for the past seven (7) years.

Nitrate plus Nitrite

Ground water concentrations of nitrite plus nitrate decreased in the off-site wells following LSE through around 2001. After 2001, wells KM-15, KM-16 and KM-18 demonstrated large variable seasonal changes with larger concentrations noted in the spring sampling events. Nitrate concentrations have been rising since 2001 and are currently 2 to 3 times the levels noted in 2001. Well KM-17 has the smallest nitrite plus nitrate ground water concentrations of all of the off-site wells and also demonstrates the smallest variability with time with an overall decreasing trend through 2004 and a range-bound or increasing trend since 2004.

5.3.2 Off-Site Metal Concentration Trends

Graphs of metal concentrations versus time include the group of metals identified by EPA as COC. COC metals versus time are presented in Appendix A and described in the following sections.

Arsenic

All off-site wells are well below the arsenic method detection limit of 5 ug/l and the RBC of 10 ug/l, as shown on Figure 4-6.

Manganese

Off-site wells are below the RBC for manganese, as shown on Figure 4-7. Concentrations of manganese in well KM-15, KM-16, and KM-18 decreased with time from initial concentrations that were greater than the RBC. Well KM-15 concentrations are approaching concentrations noted in deeper well KM-18. Well KM-17 ground water manganese concentrations remain low, near the detection limit. Well KM-16 indicates an overall decreasing trend to 2009 with a flattening trend since that time and seasonal trends between rounds. Larger concentrations generally tend to occur during spring sampling rounds. Decreases in manganese concentrations in KM-16 show a lag time behind the other off-site wells.

Manganese concentrations at the Evergreen site also show a general decline in manganese with time. During the 2012 sampling event, excessive turbidity resulted in large manganese concentrations in wells EV-1 and EV-2. This relationship between excessive turbidity and larger manganese concentrations in the sample results is documented from previous sampling events on site (Dames & Moore, 1995).

Molybdenum

All off-site wells currently exceed the molybdenum RBC of 180 ug/l. Ground water from wells at the Evergreen site also exceed the RBC for molybdenum. Distributions of molybdenum in the ground water are shown on Figure 4-8. Ground water molybdenum concentrations in wells KM-15 and KM-18 are very similar, and both peaked during pond operation and then began to decline after 1993. Both wells have similar concentration trends and both indicate significant concentration decreases with time through 2010. The decreasing trend initially slowed after 2000 and molybdenum concentrations have essentially been range-bound for the past six (6) years. Spikes in the off-site wells are noted in 2006 and again in 2011, periods that correspond with larger annual average moisture (Figure 2-2).

Concentrations of molybdenum in well KM-16 decreased following remedy completion through 2004 with notable seasonality through 2001. Increased concentrations typically occur in the spring during periods of higher water level elevations. KM-16 molybdenum concentrations spiked in the spring of 2006 and again in 2011. However, concentrations of molybdenum have been range-bound at well KM-16 since 2004. KM-17 molybdenum concentrations increased between 1998 and 2003 then declined slightly to the current concentrations. Molybdenum in well KM-17 continues to remain above the RBC and within the molybdenum ranges noted in the ground water from wells KM-15 and KM-18. Well KM-17 does not define the eastern extent of ground water exceeding the RBC, as shown on Figure 4-8. The easternmost boundary for the RBC is defined loosely by Finch Spring concentrations.

Vanadium

Off-site wells currently exceed the 260 ug/l RBC for vanadium with the exception of well KM-17, which has demonstrated relatively unchanged concentrations since November 1997. Concentrations of vanadium in wells KM-15 and KM-18 peaked prior to 1993 during pond operations and began to decline after diversion of the S-X stream to the scrubber pond and elimination of the MAP ponds. Both wells KM-15 and KM-18 have parallel and decreasing concentration trends, with well KM-18 having a consistently smaller concentration. Both wells indicate decreasing concentration trends over time, with a flattening of the trends after 2000. Concentrations of vanadium appear range-bound since 2008 at levels above the RBC. Well KM-16 has the largest ground water vanadium concentration of all off-site wells. Well KM-16 vanadium concentrations spiked in 2006 and again in 2011, both years with above average annual precipitation rates. Concentrations of vanadium in well KM-16 appear range-bound for the past five (5) years.

Vanadium concentrations at the Evergreen facility show little change since monitoring began in 2004. Concentrations of vanadium are essentially unchanged, or appear to have slightly increased since 2004.

5.3.3 Organics

Organics are no longer sampled in the off-site wells. TPH was last sampled off-site in November 1996. Concentrations of TPH remained relatively unchanged with time. Concentrations of TPH during 1996 were reported at the detection limit. TBP concentrations increased through May 1994 in the off-site wells and then decreased to less than the RBC in October 1995. TBP in well KM-16 was not detected after May 1993.

5.3.4 Conclusions of Off-Site Well Concentration Trends

Conclusions drawn from the review of off-site well concentration trends include:

- Off-site wells exceed the RBC for molybdenum and vanadium (except KM-17 that is less than the RBC for vanadium), but are below the RBC for arsenic, manganese, and assumed to be below the RBC for organics. Concentrations decreased with time following LSE, although a concentration spike was noted in some wells in 2006 and again in 2011.
- Concentrations of common ions and TDS continue to generally decrease with time following LSE and reclamation. Concentration decreases of common ions flattened in KM-16 with a number of parameters spiking in concentration in 2006 and in 2011.
- Nitrate plus nitrite concentrations suggest strongly seasonal trends with a rising trend in nitrate noted in wells KM-15, KM-16 and KM-18 after 2001. Concentrations have at least doubled in the wells since 2001.
- Concentrations of molybdenum and vanadium in Evergreen wells are consistent with concentrations noted in the off-site wells. Molybdenum appears to be declining in concentration over time, but vanadium concentrations remain relatively unchanged since 2005 or have slightly increased at some locations.

5.4 Off-Site Surface Water Quality Concentration Trends

Surface water quality is routinely monitored at four spring locations on a semiannual basis. Springs that are sampled in this effort include Finch Spring, Big Spring, and Upper and Lower Ledger Springs. Upper and Lower Ledger Springs are utilized for the City of Soda Springs Public Water Supply. Spring samples are analyzed for general indicator parameters, common ions, and metals. Concentrations versus time graphs for these springs are presented in Appendix A.

Finch Spring originates from the base of the Finch Spring Fault scarp, at a location that is approximately 4000 feet to the south of the former Tronox facility. Finch Spring has been routinely sampled since 1991. Flow from this spring discharges to a pond that flows to Kelly Park. Discharge from Finch Spring is typically less than 50 gpm.

Big Spring was initially sampled by Kerr-McGee in 1993. This spring is impacted by the plant site and the Monsanto facility. Flow from this spring is considerably greater than Finch Spring discharge, although Big Spring flow was smaller between 2001 and 2004 due to several years of below normal precipitation. Discharge from Big Spring was approximately 18.6 cubic feet per second (cfs) in May 2012.

Big Spring is the most distant spring from the site, located approximately 2.8 miles south of the facility and south of the town of Soda Springs. Big Spring is located at the most downgradient surface water discharge point in the valley, flowing through the fish hatchery adjacent to the Bear River. Big Spring emerges from alluvium at the south end of the valley floor and flows into Hatchery Creek and then into the Bear River.

Upper and Lower Ledger Spring discharge at a location approximately less than one half mile feet to the southeast of Finch Spring. Both springs issue from the basalt aquifer. During June 2000, EPA requested that Kerr-McGee resume routine sampling of Upper and Lower Ledger Springs. These springs were first sampled by Kerr-McGee in 1991. These springs are one primary source of drinking water for the City of Soda

Springs. Sample results with time are presented for Upper and Lower Ledger Springs in Appendix A. Concentrations of COC metals are typically less than detection in Upper and Lower Ledger Springs, although molybdenum and vanadium are occasionally detected at concentrations near the detection limit.

5.4.1 Common Ions and General Indicators

TDS

TDS concentrations at Finch Spring increased through October 1994 as the result of pond operation at the site and changes in the discharge of the S-X stream. TDS concentrations decreased steadily between 1995 and 2002, with a smaller seasonally-affected decreasing trend between 2002 and 2012.

Small seasonal trends are noted in the Big Spring TDS data. Concentrations of TDS at Big Spring decreased consistently since 1996 to current levels of less than 600 mg/l that are comparable to, but slightly greater than Finch Spring. TDS concentrations decreased steadily in Big Spring between 1995 and 2001. Between 2001 and 2012, the decreasing TDS trend flattened substantially when compared with the rate prior to 2001.

TDS concentrations in Ledger Springs were 460 mg/l in May 2012. Lower Ledger generally has indicated slightly larger concentration than Upper Ledger in past sampling events. TDS concentrations at the Ledger Springs are less than the concentrations at Big and Finch Spring, and are more representative of background water quality concentrations. Concentrations appear seasonal, and trends suggest seasonal but generally decreasing TDS concentrations since 2000.

Chloride

Chloride is a conservative tracer because transport in ground water is generally through the hydrodynamic process, traveling essentially at the same rate as ground water flow.

Therefore, changes in chloride concentrations at Finch Spring reflect process and remedial changes at the plant.

Concentrations of chloride at Finch Spring increased through October 1994, peaked again in late 1996, and then decreased in concentration through 2012 below 1991 levels. Concentration decreases slowed between 1999 and 2002, but continued a slower decrease in concentration through the present.

Chloride concentrations decreased in Big Spring after 1996. The decreasing chloride trend continued, but flattened between 2001 and 2012. The chloride concentrations at Ledger Springs are an order of magnitude less than chloride concentrations at Big and Finch Springs and represent background. Chloride concentrations at both Ledger springs are typically between about 4 to 6 mg/l.

Sulfate

Sulfate trends at Finch Spring are remarkably similar to the chloride trends. Sulfate peaked in October 1994 and 1996, and then decreased to the present concentration levels. Changes in Finch Spring sulfate concentrations are related to former S-X stream discharges to the scrubber pond. Concentrations of sulfate at Finch Spring are smaller than 1991 concentrations. The sulfate trend at Finch Spring is relatively flat after 2005.

Sulfate concentrations at Big Spring are typically greater than the concentration at Finch Spring. Big Spring also indicates a steady decrease with time between 1994 and 2010, with little change in concentration since 2010. The Ledger Springs sulfate concentrations are also smaller than sulfate concentrations at Big and Finch Springs, and are approximately 33 mg/l. Seasonal trends are noted, but no long-term trends are noted for sulfate in Ledger Springs.

Nitrate plus Nitrite

Nitrate plus nitrite concentrations are similar at Finch and Big Springs locations, with slightly larger concentration at Big Springs. Both locations suggest slight seasonal trends in the data, with larger concentrations occurring in the fall season. Both locations indicate generally decreasing concentration trends with time through 2001 and a range-bound but seasonal trend between 2001 and 2012. Ledger Spring nitrate plus nitrite concentrations peaked in 2011 but are an order of magnitude lower than the primary drinking water MCL and the nitrate plus nitrite concentrations at Big and Finch Springs. Data suggest an increasing nitrate trend at these springs over time, with spikes occurring in 2006, 2009 and 2011. These three years also represent years with increased annual moisture rates.

5.4.2 Metals Concentration Trends

Graphs of metals versus time are presented in Appendix A and described in the following sections.

Arsenic

Arsenic concentrations are less than the RBC and reporting limit at all spring surface water locations during 2012.

Manganese

Concentrations of manganese are less than the RBC and generally less than, or near the reporting limit at Finch Spring. Concentrations of manganese are less than the reporting limit at Upper and Lower Ledger spring locations in 2012.

Molybdenum

Historic increases and decreases in molybdenum concentrations for Finch Spring were noted during the RI (Dames & Moore, 1995) to be related to changes in the discharge locations of the S-X stream. Concentrations of molybdenum at Finch Spring indicate decreasing trends between 1991 and 1996. After 1996, the molybdenum concentration peaked for a second time in July 1997. Concentrations of molybdenum at Finch Spring decreased steadily between 1997 and 2009 to less than the RBC of 180 ug/l. Finch Spring remained below the RBC after 2008 and the trend remains steady.

Molybdenum concentrations increased at Big Spring through 1997 then decreased through 2012 with small seasonal variability. The molybdenum concentration fell below the RBC of 180 ug/l in 2009 and remained below the RBC, with the exception of the May 2012 sampling event.

Molybdenum was detected on one occasion at Upper Ledger Springs in May 2012. Molybdenum has been detected at the Ledger Springs infrequently at levels near or below the reporting limit since 2000.

Vanadium

Finch Spring demonstrates an overall increase in vanadium since monitoring began in 1991. Vanadium concentrations increased sharply at Finch Spring through 2001. Concentrations of vanadium peaked in Finch Spring during 2001 at a concentration of 92 ug/l and then demonstrated a variably decreasing trend to 46 ug/l in 2012. Increases in vanadium concentrations at Finch Spring are believed to be the result of operational S-X stream discharges to the scrubber pond. Vanadium was detected at a small concentration of 3.4 ug/l in Big Spring in May 2012. Vanadium concentrations ranged from 1.2 to 1.9 ug/l at the Ledger Springs in 2012.

6.0 PROJECTED CONCENTRATION DECAY TRENDS

6.1 General

Ground water and surface water samples collected following the site remedy completion have shown a variety of trends and patterns in the concentration levels that have become evident over the past 15 years. While a few wells show highly variable or irregular concentration patterns, many of the sample results demonstrate a pattern of initial rapid decline after LSE followed by a notably slower decline. Where appropriate, regression analysis can be useful in estimating and assessing the significance of observed trends and in predicting expected levels of contaminant concentrations at future points in time (EPA, 1992). Regression analysis is a statistical technique for fitting a theoretical curve to a set of sample data. Regression analysis provides a method for modeling (i.e., describing) the rate of this decrease. In ground-water monitoring studies, regression techniques can be used to (1) detect trends in contaminant concentration levels over time, (2) determine variables that influence concentration levels, and (3) predict chemical concentrations at future points in time (EPA, 1992). The goal of a regression analysis is to estimate the underlying functional relationship (i.e., the model), assess the fit of the model, and, if appropriate, use the model to make predictions about future observations (EPA, 1992).

COC concentration trends with time and projected trends for these wells are presented in Appendix B. Projected trends are based on the post-LSE monitoring period data. Currently, about 87 percent of the sampled wells exceed the RBC for molybdenum or vanadium. The projected period into the future varies between wells in order to demonstrate the approximate time when the COC is projected to fall below the RBC based on the regression. The purpose of the trend evaluation is to assess the likelihood of the remedy to achieve the cleanup goals. To accomplish this, ground and surface water COC data (specifically molybdenum and vanadium and manganese for KM-3 and KM-8) were evaluated for the period following cessation of the last of the uncontrolled waste stream discharges (October 1997) to estimate the relative change in ground

water COC concentrations that resulted from LSE. The calcine was not capped until approximately four (4) years after the ponds were taken out of service, so effects of the infiltration and ponding within the calcine area affected some of the early time COC concentration data for wells KM-2, KM-3 and KM-4.

Methods used to evaluate the data include: 1) regression analyses that are discussed in this section with the regression curves, and; 2) regression equations and coefficients that are presented in Appendix B. Data are evaluated as non-linear in nature based on data observation following site remedy implementation. Two data sets were evaluated by this method. The first data set included vanadium and molybdenum data from the post-LSE period (November 1997 to October 2012), the period following the implementation of the remedial actions. This data set was prepared to focus the evaluation on the trends following the implementation of the remedial actions. The second evaluated set of data includes vanadium and molybdenum data results from an arbitrarily shorter period of time (May 2004 through October 2012). This shorter period of time that is approximately midway between remedy completion in 1997 and the present. These data were evaluated in conjunction with the November 1997 through October 2012 data set to assess whether the shorter period (later-time data set) demonstrates trends that are notably different from the overall LSE time period. These evaluations were completed for each point of compliance well, off-site monitor well and spring that currently exceeds or recently exceeded the RBC. The purpose of this evaluation was to estimate when cleanup performance standards can reasonably be expected to be met for ground water.

6.2 Analytical Method

Ground water data were evaluated using a statistical forecast function for exponential decay. A forecast calculates or predicts a future value by using existing values. The predicted value is a y-value (future concentration of a COC in ground water) for a given future date. The known values are ground water data from the wells. A forecast statistically predicts future values based on a regression function of a range of known

data or known x- and y-arrays. Regression analysis estimates the relationship between variables, so that a given variable can be projected from one or more other variables.

Data curves for the ground water concentrations shown in Appendix B were generated using an exponential function that describes decay of a substance and calculates the least squares fit through points by using the equation:

$$y = ce^{-kt}$$

where:

e is the base of the natural logarithm;

c is a constant at y_0 (initial concentration) at $t = 0$, and;

$-kt$ is a constant for the predicted time, with the minus sign representing decay of concentration with time.

A trend line, the equation for that trend line and the coefficient of determination are generated for the data set based on known x-values for the best-fit curve. The y intercept for the regression trendline is set at zero. This is appropriate, based on the assumed absence of manganese, molybdenum and vanadium concentrations in background ground water quality data.

6.3 Results of Regression Analysis

An analysis using the November 1997 through October 2012 and the May 2004 through October 2012 data sets provide an estimate when these concentrations may potentially fall below their respective RBC for molybdenum and vanadium. Results of the predictions based on the 1997 to 2012 data are summarized in Table 6-1. Projections for COC based on the 2004 to 2012 data are summarized in Table 6-2. Results of the trendline analyses are presented on the Figures in Appendix B. TBP and TPH data from wells other than KM-8 are not available, and therefore are not included in this analysis. It is possible that future ground water concentration trends may differ from results generated using the two data sets, or that future trends may fall in between the

projections based on each data set. The minimum range of each graph has been set at the respective RBC.

Arsenic was detected during the RI in the limestone settling ponds at a concentration of 190 ug/l with much smaller concentrations in the MAP (14.7 ug/l) and scrubber pond (8 ug/l). Arsenic is not evaluated in the regression analysis because concentrations were less than detection in most wells between 1999 and 2007. Following 2007, the arsenic method detection limit was lowered to 5 ug/l and most of the wells are less than the RBC of 10 ug/l. The large variability of arsenic in well KM-8 ground water indicates no clear trend relative to the time of pond elimination. There is also no clear trend for arsenic in wells KM-2, KM-3 and KM-4 near the covered scrubber pond where arsenic concentrations are close to the RBC.

Manganese is evaluated for wells KM-3 and KM-8. Both wells KM-3 and KM-8 demonstrate increasing manganese concentrations in ground water with time. The remaining wells demonstrate that manganese concentrations in the ground water are less than the RBC.

Projected concentration decay trends are estimated where possible, using a regression trend curve fitted to the real-time monitoring data from ground water where the COC currently exceed the risk-based concentrations of manganese, molybdenum and vanadium. These COC were selected because most of the risk in ground water is driven by the occurrence of these metals. The time periods used to evaluate the projected COC trends included the period from November 1997 (the first round of ground water collected from the monitoring points following LSE) through the October 2012 round and a shorter period, from May 2004 to the present.

Data analyzed to project future trends include ground water results obtained from wells KM-2, KM-3, KM-5, KM-6, KM-8, KM-9, KM-12 and KM-13 that are located on the vanadium plant site; and off-site wells KM-15, KM-16, KM-17 and KM-18 that are

located south of the site. Finch Spring and Big Spring are also evaluated. Plotted results of the regression analysis are presented in Appendix B.

Results of the predictions based on the 1997 to 2012 data are summarized in Table 6-1. Projections for COC based on the 2004 to 2012 data are summarized in Table 6-2. These tables show the May 2012 concentrations from each well, the year that each COC is projected to fall below the RBC, the regression equation, the coefficient of determination (R^2) and correlation coefficient (R) for each of the evaluated cases. The larger the correlation coefficient (closest to 1.0), the stronger the correlation, or the strength of the relationship between variable data points. The coefficient of determination (R^2) is a measure of how well the regression line represents the data and provides the proportion of the fluctuation in the data that is predictable from the previous data point. A perfect fit (i.e., when all of the observed data points fall on the fitted regression line) would be indicated by an R^2 equal to 1.0. In practice, a value of R^2 of 0.6 or greater is usually considered to be high and thus an indicator that the model can be reasonably used for predicting future observations; however, it is not a guarantee (EPA, 1992). In order to identify which predictive analyses have a greater degree of certainty, values with a coefficient of determination presented on Tables 6-1 and 6-2 that exceed 0.6 (>0.6) are shaded green, while those values that are less than reliable to predict future concentrations (<0.6) are shaded in red.

A review of Table 6-1 indicates the following:

- Manganese trends for well KM-3 and KM-8 cannot be predicted based on the data that suggest increasing trends;
- Regression curves fitted to molybdenum concentrations in wells KM-3, KM-5, KM-6 and KM-8 result in a coefficient of determination that is less than 0.6 and predicted times of about 10 to more than 50 years after the remedy to fall below the RBC;
- Regression curves fitted to vanadium concentrations in wells KM-3, KM-5, KM-6 and KM-8 result in a coefficient of determination that is less than 0.6 and

predicted times of about 40 to more than 100 years following LSE to fall below the RBC;

- Regression curves fitted to molybdenum concentrations in wells KM-2, KM-12, KM-13, KM-15, KM-16, KM-17 and KM-18 result in a coefficient of determination that is greater than 0.6 and predicted times of about 20 to more than 35 years to fall below the RBC following remedy completion;
- Regression curves fitted to vanadium concentrations in wells KM-2, KM-12, KM-13, KM-15, KM-16, KM-17 and KM-18 result in a coefficient of determination that is greater than 0.6 and predicted times of about 20 to more than 60 years to fall below the RBC following remedy completion, and;
- Regression curves fitted to molybdenum concentrations for Finch and Big Spring result in a coefficient of determination that is greater than 0.6. These locations were below the RBC for molybdenum in October 2012 and the large coefficient of determination indicates a strong correlation with the data.

The wells with molybdenum and/or vanadium concentrations that cannot be reliably predicted include shallow wells that are located near the former process ponds that were not investigated during the RI/FS. Well KM-5 located near the former historic scrubber and MAP ponds achieved molybdenum cleanup levels in 2008, but returned above the RBC in 2011. Hence, the small R^2 value, indicating the period of time required to achieve the RBC cannot be projected with certainty.

Results of the regression analysis for the 2004 to 2012 data set are presented in Table 6-2. In most cases, this data set includes concentration results that are decreasing at a protracted rate when compared with early time data following LSE. Outlier concentrations for some of the wells in 2006, 2009 and 2011 that were previously noted in the text in Chapter 4 result in a poorer fit of the data to the regression, therefore the estimated time to reach the RBC cannot be reliably projected. A review of Table 6-2 indicates the following:

- Manganese trends for well KM-3 and KM-8 cannot be predicted based on the data that show increasing trends;

- Regression curves fitted to molybdenum concentrations in wells KM-5, KM-6, KM-8, KM-13, KM-15, KM-16 and KM-18 result in a coefficient of determination that is less than 0.6 and either increasing in concentration or resulting in predicted times of about 20 to more than 90 years after the remedy to fall below the RBC;
- Regression curves fitted to vanadium concentrations in wells KM-2, KM-3, KM-5, KM-6 and KM-8, KM-15 and KM-16 result in a coefficient of determination that is less than 0.6 and predicted times of about 60 to more than 100 years following LSE to fall below the RBC;
- Regression curves fitted to molybdenum concentrations in wells KM-2, KM-3, KM-12 and KM-17 result in a coefficient of determination that is greater than 0.6 and predicted times of about 20 to more than 100 years to fall below the RBC following remedy completion, and;
- Regression curves fitted to vanadium concentrations in wells KM-9, KM-12, KM-13, and KM-18 result in a coefficient of determination that is greater than 0.6 and predicted times of about 20 to more than 40 years to fall below the RBC following remedy completion;

Results evaluated since May 2004 show that the time to reach the RBC could be substantially longer than the estimated times from the larger 15-year data set, which is expected because of the observed slowing nature of the concentration decreases. The data set also indicates fewer wells with reliable coefficient of determination values compared with the larger data set. This is due to the fact that the 2004 to 2012 data set, for the most part, contains data spikes, is range-bound, or exhibits a rate of decrease that is substantially slower than the period immediately following LSE.

Regardless of the certainty of the predictions offered by the larger coefficient of determinations for the well-matched curves, all of the wells will take considerably longer than originally predicted by ground water modeling (GET, 2012) to reach the respective RBC for each COC.

7.0 CONCLUSIONS

Kerr-McGee discontinued waste-water discharges to a number of unlined process ponds (S-X, limestone settling, scrubber, calcine) between 1995 and 1997. Ground water data indicate that these efforts enacted prior to and during 1997 resulted in notable ground water concentration decreases at most of the on-site, point of compliance, and off-site well locations and off-site springs. During 2012, a number of the wells demonstrated ground water COC concentration trends that have flattened or are somewhat range-bound at concentrations that are above the risk-based concentration. A few wells have ground water concentration trends that indicate increasing COC since remediation was completed.

Projected future concentrations that are based on a data regression for the time period since the ponds were removed from service indicate that some of the COC will persist in the ground water for a considerable period of time (greater than 100 years), or that concentrations will not achieve clean-up levels. Analysis of the same data over a shorter period of time (2004 to 2012) results principally in more wells with greater uncertainty and a later projected date when concentrations will fall below risk-based levels. Wells that indicate uncertainty in reasonably achieving clean up goals include wells located near previously uninvestigated pond sites including the former scrubber pond, wells that are interior to the site (wells KM-4 and KM-7) and well KM-8 that monitors ground water to the south of the historic S-X pond.

Based on a review of water quality results through October 2012, distribution of site contaminants in the aquifer, recent water quality trends, and predictions of future concentrations, the following conclusions are drawn.

On-site Water Quality Conclusions

- Water level gradients and ground water flow directions both on and off site remain relatively unchanged when compared with previous assessments. The Evergreen

water level data indicates that the gradient is steeper to the west on the downthrown block than the gradient to the east of the fault.

- Vanadium and molybdenum concentrations continue to exceed the RBC at most of the on-site POC wells and non-POC wells.
- The largest continued on-site impacts to ground water occur immediately downgradient or south of the former scrubber and S-X pond basins. Projected time periods for concentrations in these wells to fall below the risk-based levels has a low level of certainty based on the fit of the data to the regression line. Evaluation of these data over a shorter time period results in greater uncertainty for concentrations to fall below the RBC.
- Generally, concentrations of common ions and TDS have decreased with time in the on-site wells. This trend has flattened somewhat between 2000 and the present for a number of the on-site wells near the west side of the facility as these concentrations approach background.
- Increased or spiked ground water concentrations noted in several wells between 2004 and 2006 and again noted in 2011 are contemporaneous with periods of increased annual moisture. Larger concentrations observed may be related to increased soil moisture residence time or the result of increased infiltration though unmitigated on-site sources.
- Nitrate continues to demonstrate a rising trend near the covered S-X pond and downgradient of the former plant site. Nitrate plus nitrite concentrations have increased seven times in well KM-8 between 2001 and 2012. A fivefold increase in nitrate plus nitrite is also noted in shallow well KM-4 southwest of the calcine cap. Nitrate began rising after 2001 and is highly variable. Spikes are noted in 2006, 2009 and 2011 in some wells.
- The site pH is neutral to slightly basic across the site and at off-site locations, with the lowest pH areas identified near the former S-X pond.
- Concentrations of TPH and TBP continue to exceed the RBC in well KM-8 ground water. TPH indicates a decreasing ground water trend through 2005 with only seasonal changes noted to the present. TBP indicates an overall decreasing trend since LSE was implemented through 2004 with a seasonal fluctuation within this range to the present.
- Concentrations of arsenic in ground water are found above the RBC in well KM-8 near former S-X pond. Arsenic is identified just above the RBC near the former scrubber pond and at small concentration in shallow ground water in on site wells not located near these sources.

- Manganese decreased with time in nearly all wells following LSE and the remedial actions completed in 1997. Manganese concentrations are found above the RBC in two wells monitoring the former S-X and scrubber ponds. Well KM-3 indicates an increasing manganese trend following implementation of LSE. Well KM-8 manganese concentrations are seasonal and have been increasing since 2004.
- On-site deep well KM-19 was below the RBC for all COC in 2012.
- The projected period of time for COC concentrations to fall below the risk-based level is substantially longer than previous ground water modeling estimates for LSE, in part because the model assumed the S-X pond and scrubber ponds would have no infiltration after closure (GET, 2012). The continued large concentrations suggests that unmitigated uninvestigated on-site solid wastes remaining from former operations continue to contribute COC to the ground water.

Off-Site Ground and Surface Water Quality Conclusions

- Evergreen and Monsanto ground water quality results used in conjunction with the site water quality data provides a clearer understanding of the off-site migration of contaminants from the site but do not identify the undefined eastern boundary of the site contaminants exceeding risk-based levels.
- Generally, common ions and TDS decreased with time in the off-site MST wells.
- Nitrate concentrations generally increased at off-site well locations after 2001. Concentrations are highly variable and are within the range of concentration noted during plant operations.
- Concentration spikes in well KM-16 in 2006 and again in 2011 correspond with a rise in ground water levels and with periods of increased annual precipitation.
- Ground water concentrations of common ions and TDS decreased in well KM-17 since peaking in 1998. Molybdenum concentrations indicate a decreasing trend in well KM-17 but levels still exceed the risk-based concentrations. The eastern extent of molybdenum in ground water exceeding the risk based level remains undetermined. Vanadium concentrations in well KM-17 are less than the RBC.
- Vanadium and molybdenum concentrations in ground water continue to exceed the RBC in off-site wells KM-15, KM-16 and KM-18. Molybdenum concentrations in these wells spiked in 2011 similar to the spikes noted in 2006. Vanadium concentrations in wells KM-15, KM-16 and KM-18 appear to be somewhat range-bound at levels that are well above the risk-based level.

- Molybdenum concentrations decreased over time at the Evergreen site since 2004. Vanadium concentrations at Evergreen are essentially unchanged or suggest slight concentration increases with time.
- Arsenic in the ground water is near the method detection limit and below RBC at all off-site well locations, but exceeds the MCL in well EV-1 at the Evergreen site. Arsenic may be increasing in well EV-1 with time.
- Manganese continues to decrease at off-site well locations and is less than the RBC at all off-site locations. Elevated manganese in the Evergreen wells in 2012 is attributed to large concentrations of turbidity.
- Finch and Big Spring fell below the RBC for molybdenum in 2009. Molybdenum trends at both locations have flattened between 2009 and the present. The RBC for molybdenum was exceeded at Big Spring in 2012 during the spring sampling event, but less than the RBC during the October sampling.
- Vanadium concentrations in Finch Spring remain elevated but are less than the RBC. Vanadium concentrations at Finch Spring indicate a decreasing trend since 2001, but levels remain elevated. Vanadium concentrations in Big Spring remain in the 3 to 4 ug/l range.
- Water quality at Upper and Lower Ledger Springs (City of Soda Springs drinking water supply) indicates very small concentrations of COC from former plant site operations based on 2012 water quality results, however, these concentrations are two orders of magnitude below risk levels. Nitrate plus nitrite concentrations in both springs have been increasing over time with the largest concentrations reported in 2011. Nitrate levels remain below the drinking water MCL.

COC Trendline Projections

- Manganese concentrations are increasing in wells KM-3 and KM-8, therefore it is not possible by methods utilized herein to predict when these concentrations will fall below the risk-based concentration. The remainder of the wells are below the RBC for manganese.
- Despite the relative confidence in the modeled predictions offered by the "best fit" regression curves matched to the observations, all of the wells will take considerably longer than originally predicted by ground water modeling to reach the respective RBC for each COC.
- Predicted future COC concentrations using data obtained following LSE results in a larger number of wells with stronger correlation and a better data "fit" compared with the same analysis using the data set from 2004 to the present. The shorter censored data set evaluation suggests a larger number of wells with weaker correlation and a

longer time period to achieve clean up levels as concentration decreases of vanadium and molybdenum have slowed considerably over the past several years.

- Data indicate that molybdenum is projected to fall below the RBC in four on-site POC wells (KM-2, KM-5, KM-12 and KM-13) and three of the off-site monitoring wells (KM-15, KM-17 and KM-18) within a period of 10 to 60 years following LSE with varying degrees of certainty. Molybdenum concentrations will continue to exceed the RBC at the on-site wells monitoring the former S-X and scrubber ponds (KM-3, KM-6 and KM-8) and off-site well KM-16 for a considerably longer period, estimated to range from about 30 to more than 100 years following LSE. In the case of well KM-8, the concentration of molybdenum cannot be projected based on increasing concentrations.
- The concentration of vanadium in the ground water is projected exceed the RBC in most on-site POC wells and off-site wells for a longer period of time than molybdenum. Concentrations of vanadium in wells KM-9, KM-12 and KM-13 are predicted to be near or below the vanadium RBC within 20 to 30 years following LSE. Vanadium ground water concentrations will continue to exceed the RBC at the shallow on-site wells monitoring the former S-X and scrubber ponds (KM-2, KM-3, KM-6 and KM-8) for considerably longer (60 to more than 100 years) following LSE. Vanadium coefficients of determination for wells KM-2, KM-3, KM-5, KM-6 and KM-8 are relatively weak.
- As a result of overall larger or fluctuating concentrations and unclear trends for arsenic, manganese, molybdenum and vanadium, well KM-8 continues to lag other wells in concentration decreases. Therefore, KM-8 will take considerably longer to fall below the RBCs for arsenic, manganese, molybdenum and vanadium, if ever. Water samples collected from this well continue to have a strong S-X pond odor when these are collected. Data projections suggest that it is possible that these ground water concentrations will not meet clean up goals unless further actions are taken at the former S-X pond location.
- Molybdenum concentrations at Big and Finch springs are projected, but not guaranteed to remain below the RBC after 2013 based on regression analysis. Results of this analysis indicate a relatively high degree of certainty.

8.0 RECOMMENDATIONS

Ground and surface water monitoring will continue at the former Tronox facility on a semiannual basis to assess the effects of remedial changes made at the site as required in the ROD and to assess areas where further site actions may be warranted. Field data results should be evaluated when sampling occurs to assess current with preceding site conditions.

Parameters that fall below the RBC will be evaluated and reported to EPA when these occur. All sampling and analytical results should be reviewed semiannually in accordance with the protocols contained in SW846 and EPA laboratory data validation functional guidelines to assess the quality of the data results. Ground and surface water quality will be appended semiannually to the RD/RA database. Results of the data review will be transmitted to the MST, EPA and IDEQ.

Ground water quality trends and predicted water quality should be evaluated in an annual report to assess the improvements to ground and surface water quality. Future annual reports should continue to include evaluation of ground water monitoring data from the off-site Evergreen facility and from Monsanto when available, in order to evaluate whether ground water flowing off the MST property is controlled to prevent consumption at levels that exceed the RBC. Evaluation of Evergreen data in conjunction with Tronox ground and surface water data will provide an increased understanding of ground water flow paths downgradient of the former vanadium plant site.

Recommended changes to the monitoring plan are presented in the approved Final Ground Water Monitoring Network Evaluation for the Kerr-McGee Chemical Corporation Superfund Site Tronox Facility Soda Springs, Idaho (GET, 2010). In general, those recommendations stated that wells with COC that show the largest variation in long-term trends and demonstrate seasonal variations are important to understanding the fate and transport of the COC relative to the remedy evaluation. These wells should

continue to be monitored at least semi-annually to document these long term and seasonal changes. Wells that indicate range-bound concentrations or that decline more slowly or are approaching steady-state conditions also help with the understanding of remedy performance. Range-bound trends, particularly those with concentrations approaching steady state at concentrations above established RBCs provide valuable information related to the effectiveness of the remedial actions in achieving cleanup goals. However, because the concentrations in these wells rarely change, less frequent monitoring is prudent. Recommended changes for long-term monitoring using the current network include:

- Continued semiannual monitoring for most POC wells that continue to show decreasing trends or seasonal fluctuating trends (wells KM-2, KM-3, KM-4, KM-6, KM-8, KM-9, KM-11, KM-12 and KM-13);
- Recommended annual monitoring (in the spring) for POC wells with flat trends and internal non- POC wells (wells KM-4 and KM-7);
- Well KM-19 has already achieved the clean-up goals and could be monitored less frequently (i.e. annually in the spring round);
- Semiannual monitoring of off-site wells and springs should continue as the result of noted significant seasonal fluctuations and the importance of these well sites for defining areas of off-site migration of COC;

For future sampling events, POC wells that indicate ground water concentrations below the RBC could have monitoring frequency reduced to annual monitoring. This will be decided on a case-by-case basis as the situation arises.

Additional investigations to assess possible on-site contributing sources and to address data gaps within the current monitoring network are warranted and are described in the recommendation section of the approved Final Addendum 1 Remedy Evaluation Report for the Kerr-McGee Chemical Corporation Superfund Site Tronox Facility Soda Springs, Idaho (GET, 2012). The MST currently plans to address these issues and solicit requests for proposals to complete a focused remedial investigation/feasibility study

work plan for the site that will result in a characterization of all contamination (source) issues that remain at the site and define the nature and extent of ground water impacts.

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TABLES

TABLE 1-1
MONITOR WELL CONSTRUCTION AND WELL TESTING RESULTS

Well Designation	Completed Date	Northing*	Easting*	Elevation Top of PVC Feet msl	Elevation Concrete Pad Feet	Top of Screen	Bottom of Screen	Hydraulic Conductivity (ft/day)	Unit Monitored **	Lithology Screened Interval
Tronox Wells										
KM-1	10/07/91	373073.394	659740.078	6029.72	6027.50	45.9	55.9	204	I4	clay, tuff
KM-2	09/21/91	371777.028	660379.196	6025.11	6023.00	47.2	57.2	266	Qb5	basalt, clay
KM-3	10/11/91	371745.657	659825.555	6014.28	6012.20	39.1	49.1	91	I4	clay, tuff
KM-4	10/02/91	372033.826	659695.190	6023.44	6021.90	43.7	53.7	153	I4	cinders, tuff
KM-5	10/01/91	372710.706	658856.602	6002.72	6001.50	38	48	37	Qb5	vesicular basalt
KM-6	09/24/91	371736.929	658601.626	5988.13	5986.00	34.7	44.7	340	Qb5	vesicular basalt
KM-7	09/26/91	372113.189	658578.407	6001.63	5999.90	46.2	56.2	na	Qb5/I4	vesicular basalt and cinders
KM-8	10/21/91	371771.964	658144.161	5976.75	5974.40	34.6	44.6	9.4	Qb5	basalt, clay
KM-9	09/29/91	371770.477	657836.280	5973.56	5971.50	47.5	57.5	48	Qb5	vesicular basalt
KM-10	10/12/91	373073.856	659761.715	6029.43	6027.90	100	120	na	Qb3	basalt
KM-11	10/29/91	371745.582	659847.119	6013.63	6012.10	80	100	96	Qb3	basalt
KM-12	10/29/91	371778.391	658119.553	5976.07	5973.90	134.1	154.1	34	Qb3	basalt
KM-13	10/07/91	372185.749	658042.505	5977.65	5975.60	46.4	56.4	17	Qb5	basalt
KM-15	09/24/92	370332.04	657491.89	5958.10	5956.20	45.2	55.2	105	Qb5a/I5	cinders, basalt
KM-16	09/18/92	371058.74	658151.12	5998.97	5997.20	63.3	73.3	97	Qb5	basalt
KM-17	09/25/92	371100.35	659365.30	6001.11	5999.60	38.2	48.2	2.3	Qb4/I3	basalt, silt
KM-18	10/03/92	370336.14	657468.67	5958.25	5956.80	152.6	172.6	8.2	Qb3	basalt
KM-19	10/15/92	371788.11	658085.74	5975.17	5973.80	193.6	213.6	15	Qb2/I1	fractured basalt, clay
Evergreen Wells										
EV-1	09/05/03	4725177	452418	5951		26	36	na		Gravel, hard basalt
EV-2	09/08/03	4725074	452491	5943		25	35	na		Gravel, broken basalt
EV-3	09/06/03	4724950	452411	5938		26	36	na		Cinders, basalt, hard basalt
EV-4	?	4725070	452378	5945		?	?	na		Unknown
Monsanto Wells										
TW-12	09/14/84	369017.37	656681.35	5939.23	5937.63	89.5	99.5	100	UBZ (I4)	Loose basalt and cinders
TW-33	12/10/84	372526.92	657699.47	5975.68	5974.03	69	74	na	UBZ	Weathered basalt and cinders
TW-38	02/13/85	370446.4	656523.94	5972.91	5970.94	90	102	na	UBZ (Qb5/I5)	Cinders, fresh basalt
TW-56	1992 ?	367979.1	656276.06	5910.2		95	105	na	UBZ (Qb3)	Basalt
Lewis Well	08/15/74	4724126.4	451791.3	5864.35		85	105	100	NA	Crevice basalt, hard basalt

* All coordinates in State Plane Coords except Evergreen and Lewis Wells

** Basalts and interflow stratigraphic units labeled sequentially from QB1/I1 (oldest flow/interflow units) to QB5A/I5 (youngest units)

TABLE 1-2
MAXIMUM CONCENTRATIONS OF COC AND MAY 2012 CONCENTRATIONS
IN TRONOX WELLS AND OFF-SITE SPRINGS

Well Designation	Arsenic Concentrations		Manganese Concentrations		Molybdenum Concentrations		Total Petroleum Hydrocarbons Concentrations		Tributyl Phosphate Concentrations		Vanadium Concentrations	
	RBC = 10 ug/l		RBC = 180 ug/l		RBC = 180 ug/l		RBC = 0.73 mg/l		RBC = 180 ug/l		RBC = 260 ug/l	
	Largest (ug/l)	MAY 2012 (ug/l)	Largest (ug/l)	MAY 2012 (ug/l)	Largest (ug/l)	MAY 2012 (ug/l)	Largest (mg/l)	MAY 2012 (mg/l)	Largest (ug/l)	MAY 2012 (ug/l)	Largest (ug/l)	MAY 2012 (ug/l)
KM-2*	53	9.9	444	31	11800	770	2.0	NA	7	NA	15500	4200
KM-3*	27	11	1680	510	44900	5500	1.8	NA	1400	NA	13200	2100
KM-4	63	11	1160	69	15300	1100	NA	NA	NA	NA	23300	7200
KM-5*	12.2	4	399	0.46	1460	180	NA	NA	3	NA	15800	1600
KM-6	6.5	5.6	291	190	2140	1200	2.0	NA	110	NA	6630	4200
KM-7	6.9	4.6	197	89	593	280	2.0	NA	NA	NA	3410	2400
KM-8*	170	45	8770	6100	165000	36000	9.5	1.4	4442	450	29000	13000
KM-9*	5	1.4	113	5.1	1740	130	NA	NA	ND	NA	3590	330
KM-11*	2	ND	157	12	5600	190	0.42	NA	112	NA	492	8.4
KM-12*	23	0.81	177	20	9290	320	0.39	NA	13	NA	5580	480
KM-13*	4	0.8	131	5.8	6790	180	0.18	NA	12	NA	6420	440
KM-15	5.6	1.3	543	35	6950	450	0.15	NA	484	NA	3840	820
KM-16	7.3	4	364	95	2300	720	1.9	NA	180	NA	4250	2200
KM-17	1.5	ND	84	6.6	987	310	1.2	NA	170	NA	493	14
KM-18	3.7	0.53	332	33	6340	340	1.3	NA	410	NA	2990	590
KM-19*	2	1	32.3	0.57	258	14	1.1	NA	4	NA	558	95
Big Spring	1.1	0.33	1.8	0.62	508	200	NA	NA	NA	NA	13.6	3.4
Finch Spring	2	0.54	4.4	0.92	663	150	0.22	NA	ND	NA	91.7	49
Upper Ledger	3.7	ND	2.6	ND	22.4	4.8	NA	NA	NA	NA	5.1	1.9
Lower Ledger	4.2	ND	1.5	ND	54.1	ND	NA	NA	NA	NA	14.9	1.2

Footnotes:

* = Point of Compliance Well

NA = Not Available – not sampled during 2012

ND = Not Detected (less than IDL)

Shaded cells indicate exceedence of RBC

TABLE 3-1

**SAMPLING HISTORY AND SAMPLING RATIONALE FOR REMEDIAL DESIGN/
REMEDIAL ACTION GROUND WATER SAMPLING**

Well/Sample Location	Source Area Monitored	Round 1 Through 8 Sample Events (Feb 1992 to May 1995)		Round 9 Through 12 Sample Events (Oct 1995 to July 1997)		RD/RA Sample Events And Low Flow Sampling		
		Sampled? (Yes/No)	Analytes	Sampled? (Yes/No)	Analytes	Sample Site? (Yes/No)	Analytes	Justification For Sampling/Not Sampling
KM-1 (shallow well paired with KM-10)	Lateral gradient background well	Yes	Long-list metals Round 1-3, short-list metals Rounds 4 through 8, radio-nuclides Rounds 1,3, total chromatographable organics Round 1	Yes	Metals, General Indicators, No organics	No	None	Background sampling not needed; relying on RBC performance standards at POC wells and no statistical background comparison
KM-2 (shallow well)	Active calcine tailing impoundment/former scrubber pond area	Yes	Long-list metals Round 1-3, short-list metals Rounds 4 through 8, radio-nuclides Rounds 1, total chromatographable organics Round 1	Yes	Metals, General Indicators, no organics	Yes	Table 4-3 of RD/RA GW SAP and QAPP; No organics	Point of compliance well, although not truly downgradient of calcine or former scrubber pond; monitor changes in ground water concentrations in conjunction with changes at active calcine impoundment area, 10-acre pond and scrubber pond closure
KM-3 (shallow well paired with KM-11)	Reclaimed scrubber pond	Yes	Long-list metals Round 1-3, short-list metals Rounds 4 through 8, radio-nuclides Rounds 1,3,4 total chromatographable organics Round 1	Yes	Metals, General Indicators, no organics	Yes	Table 4-3 of RD/RA GW SAP and QAPP; no organics	Point of compliance well; monitor changes in ground concentrations water along southern plant boundary in conjunction with scrubber pond closure
KM-4 (shallow well)	Active calcine tailing impoundment area	Yes	Long-list metals Round 1-3, short-list metals Rounds 4 through 8, radio-nuclides Rounds 1, 3, total chromatographable organics Round 1	No	None	Yes	Table 4-3 of RD/RA GW SAP and QAPP, no organics	Provides monitoring of calcine impoundment following capping. Not a POC well

TABLE 3-1

**SAMPLING HISTORY AND SAMPLING RATIONALE FOR REMEDIAL DESIGN/
REMEDIAL ACTION GROUND WATER SAMPLING**

Well/Sample Location	Source Area Monitored	Round 1 Through 8 Sample Events (Feb 1992 to May 1995)		Round 9 Through 12 Sample Events (Oct 1995 to July 1997)		RD/RA Sample Events And Low Flow Sampling		
		Sampled? (Yes/No)	Analytes	Sampled? (Yes/No)	Analytes	Sample Site? (Yes/No)	Analytes	Justification For Sampling/Not Sampling
KM-5 (shallow well)	Historic scrubber pond/historic MAP ponds, Boiler blowdown pond/downgradient of facility	Yes	Long-list metals Round 1-3, short-list metals Rounds 4 through 8, radio-nuclides Rounds 1,3, total chromatographable organics Round 1	Yes	Metals, General Indicators, no organics	Yes	Table 4-3 of RD/RA GW SAP and QAPP; No organics	Point of compliance well, monitors downgradient of northern and central areas of entire plant facility and historic scrubber pond
KM-6 (shallow well)	Historic limestone Settling ponds	Yes	Long-list metals Round 1-3, short-list metals Rounds 4 through 8, radio-nuclides Rounds 1,3, total chromatographable organics Rounds 1, 3	No	None	Yes	Table 4-3 of RD/RA GW SAP and QAPP; no organics	Monitors zone of increased transmissivity on the southern boundary of facility; not a POC well
KM-7 (shallow well)	Historic calcine impoundment area	Yes	Long-list metals Round 1-3, short-list metals Rounds 4 through 8, radio-nuclides Rounds 1,3, total chromatographable organics Round 1	No	None	Yes (2000-->)	Table 4-3 of RD/RA GW SAP and QAPP; no organics	Monitors central portion of the facility within the west calcine area and provides additional justification for contouring of COC; not a POC well
KM-8 (shallow well paired with KM-12 and KM-19)	Former S-X pond/ downgradient of plant facility	Yes	Long-list metals Round 1-3, short-list metals Rounds 4 through 8, metals, radionuclides Rounds 1, 4, total chromatograph-able organics Round 1,3, TPH and semivolts Rounds 4 and 8	Yes	Metals, General Indicators	Yes	Table 4-3 of RD/RA GW SAP and QAPP	Point of compliance well; monitor changes in ground water concentrations in conjunction with changes from S-X pond closure

TABLE 3-1

**SAMPLING HISTORY AND SAMPLING RATIONALE FOR REMEDIAL DESIGN/
REMEDIAL ACTION GROUND WATER SAMPLING**

Well/Sample Location	Source Area Monitored	Round 1 Through 8 Sample Events (Feb 1992 to May 1995)		Round 9 Through 12 Sample Events (Oct 1995 to July 1997)		RD/RA Sample Events And Low Flow Sampling		
		Sampled? (Yes/No)	Analytes	Sampled? (Yes/No)	Analytes	Sample Site? (Yes/No)	Analytes	Justification For Sampling/Not Sampling
KM-9 (shallow well)	Former S-X pond/downgradient of plant facility	Yes	Long-list metals Round 1-3, short-list metals Rounds 4 through 8, radio-nuclides Rounds 1,3, total chromatographable organics Round 1	Yes	Metals, General Indicators, no organics	Yes	Table 4-3 of RD/RA GW SAP and QAPP; No organics	Point of compliance well, downgradient of entire facility; comparisons were made with RI ground water model results
KM-10 (intermediate well, paired with KM-1)	Intermediate depth background well	Yes	Long-list metals Round 1-3, short-list metals Rounds 4 through 8, radio-nuclides Rounds 1,3, total chromatographable organics Round 1	Yes	Metals, General Indicators, no organics	No	None	Background sampling not needed; relying on RBC performance standards at POC wells and no statistical background comparison
KM-11 (intermediate well, paired with KM-3)	Former scrubber pond	Yes	Long-list metals Round 1-3, short-list metals Rounds 4 through 8, radio-nuclides Rounds 1,3, total chromatographable organics Round 1	Yes	Metals, General Indicators, no organics	Yes	Table 4-3 of RD/RA GW SAP and QAPP; No organics	Point of compliance well; monitor changes in ground water concentrations in conjunction with scrubber pond closure
KM-12 (intermediate well paired with KM-8, KM- 19)	Former S-X pond/ downgradient of plant facility	Yes	Long-list metals Round 1-3, short-list metals Rounds 4 through 8, radio-nuclides Round 1, total chromatographable organics Round 1	No	None	Yes	Table 4-3 of RD/RA GW SAP and QAPP, no organics	Point of compliance well; monitor changes in ground water concentrations in conjunction with changes from S-X pond closure
KM-13 (shallow well)	Former S-X pond (north end) and downgradient of plant facility	Yes	Long-list metals Round 1-3, short-list metals Rounds 4 through 8, radio-nuclides Round 1, total chromatographable organics Round 1	Yes	Metals, General Indicators, no organics	Yes	Table 4-3 of RD/RA GW SAP and QAPP; no organics	Point of compliance well, downgradient of entire facility

TABLE 3-1

**SAMPLING HISTORY AND SAMPLING RATIONALE FOR REMEDIAL DESIGN/
REMEDIAL ACTION GROUND WATER SAMPLING**

Well/Sample Location	Source Area Monitored	Round 1 Through 8 Sample Events (Feb 1992 to May 1995)		Round 9 Through 12 Sample Events (Oct 1995 to July 1997)		RD/RA Sample Events And Low Flow Sampling		
		Sampled? (Yes/No)	Analytes	Sampled? (Yes/No)	Analytes	Sample Site? (Yes/No)	Analytes	Justification For Sampling/Not Sampling
KM-15 (shallow well, paired with KM-18)	Off-site well southwest of former S-X pond and within main area of impacted ground water	Not completed prior to Round 5	Long-list metals Round 5, short-list metals Rounds 6 through 8, semivols and TPH Rounds 5-8	Yes	Metals, General Indicators	Yes	Table 4-3 of RD/RA GW SAP and QAPP; no organics	Located in off-site area near modeled point; current RBC exceedences of Mo, and V
KM-16 (shallow well)	Off-site well south of former S-X and settling ponds	Not completed prior to Round 5	Long-list metals Round 5, short-list metals Rounds 6 through 8, semivols and TPH Rounds 5-8	Yes	Metals, General Indicators	Yes	Table 4-3 of RD/RA GW SAP and QAPP, no organics	Located off-site and laterally downgradient of the site; RBC exceedences of Mo, and V
KM-17 (shallow well)	Off-site well southwest of former scrubber pond and active calcine tailing	Not completed prior to Round 5	Long-list metals Round 5, short-list metals Rounds 6 through 8, semivols and TPH Rounds 5-8	Yes	Metals, General Indicators	Yes	Table 4-3 of RD/RA GW SAP and QAPP, no organics	Located off-site and laterally downgradient of the site; RBC exceedences of Mo ; does not identify easternmost RBC limit
KM-18 (intermediate well, paired with KM-15)	Off-site well southwest of former S-X pond, pond and within main area of impacted ground water, paired with KM-15	Not completed prior to Round 5	Long-list metals, semivols and TPH Rounds 5-8	Yes	Metals, General Indicators	Yes	Table 4-3 of RD/RA GW SAP and QAPP, no organics	Monitors deeper aquifer zone for ground water impact; current RBC exceedences Mo, and V; Vertically downward gradient
KM-19 (deep well paired with KM-8 and KM-12)	Former S-X pond and downgradient of plant facility	Not completed prior to Round 5	Long-list metals Round 5, short-list metals Rounds 6 through 8, semivols and TPH Round 5	No	None	Yes	Table 4-3 of RD/RA GW SAP and QAPP; no organics	Point of compliance well; monitor changes in ground water concentrations in conjunction with changes from S-X pond closure

TABLE 3-1

**SAMPLING HISTORY AND SAMPLING RATIONALE FOR REMEDIAL DESIGN/
REMEDIAL ACTION GROUND WATER SAMPLING**

Well/Sample Location	Source Area Monitored	Round 1 Through 8 Sample Events (Feb 1992 to May 1995)		Round 9 Through 12 Sample Events (Oct 1995 to July 1997)		RD/RA Sample Events And Low Flow Sampling		
		Sampled? (Yes/No)	Analytes	Sampled? (Yes/No)	Analytes	Sample Site? (Yes/No)	Analytes	Justification For Sampling/Not Sampling
Finch Spring (spring discharging from base of Finch Fault to surface water)	Spring south of facility which has appeared to be impacted primarily from scrubber discharge	Yes	Long-list metals Round 1-3, short-list metals Rounds 4 through 8, long-list metals, semivolts and TPH Round 5	Yes	Metals, General Indicators	Yes	Table 4-3 of RD/RA GW SAP and QAPP, no organics	Monitor downgradient changes to ground water from scrubber pond closure and other remedial actions on-site, below RBC for Mo in 2012
Big Spring (spring discharging to surface water flowing to Bear River)	Spring south of Soda Springs, furthest south discharge identified from Bear River Basin to Bear River	Not sampled prior to Round 6	Short-list metals	Yes	Metals, General Indicators, no organics	Yes	Table 4-3 of RD/RA GW SAP and QAPP, no organics	Below RBC for Mo in 2012; furthest monitoring point downgradient of plant site, will continue to monitor
Upper Ledge(r) Spring (spring discharging from Ledger Creek drainage, between Kelley Park and Rabbit Mountain	An important source of drinking water for the town of Soda Springs. EPA requested additional monitoring of this spring by KMC LLC following public meeting and on amended ROD comments in June 2000.	1 Event (no impacts noted)	Long-list metals Round 1	No	None	Yes	Table 4-3 of RD/RA GW SAP and QAPP, no organics	Monitor ground water quality
Lower Ledge(r) Spring (spring discharging from Ledger Creek drainage, between Kelley Park and Rabbit Mountain	An important source of drinking water for the town of Soda Springs. EPA requested additional monitoring of this spring by KMC LLC following public meeting and on amended ROD comments in June 2000.	1 Event (no impacts noted)	Long-list metals Round 1	No	None	Yes	Table 4-3 of RD/RA GW SAP and QAPP, no organics	Monitor ground water quality

TABLE 5-1
CHRONOLOGY OF PROCESS CHANGES

Event	Date(s)	Comments
S-X stream diverted from the S-X pond to the scrubber pond	1992 through 1993	Flow may have been diverted between ponds during this time period.
MAP ponds taken out of service; third roaster taken off-line in April	1993	Ponds reclaimed. Effects of remediation apparent in well KM-5.
S-X pond receiving discharge from S-X circuit	1994	S-X circuit discharge diverted to S-X pond for last time.
S-X stream diverted from the S-X pond to the scrubber pond	Late 1994 to mid 1995	S-X pond contained residual process water during 1995
S-X stream diverted to newly-constructed lined ponds	Mid 1995	Precipitation continued to fill the S-X pond basin and infiltrate. Pond contained significant volume of precipitation during 1996-1997 winter.
Scrubber pond taken out of service	April 1997	Scrubber pond pumped to the calcine pond. Some scrubber stream sent to calcine ponds. Residual liquid in pond and meteoric water drained out during stabilization of the pond sediments. All baghouses on-line in October.
Discontinue sluicing calcine	April – October 1997	Calcine dewatered, and residual water recycled in process. Dewatered calcine stockpiled north of the calcine impoundment.
Fertilizer Plant Operational	July 1998 to May 2000	Calcine removed from active calcine Impoundment, processed to fertilizer. Reject fertilizer placed in calcine impoundment.
Discontinue Vanadium Processing – Vanadium Plant Idle	January 1999 to present	Discontinue stockpiling of calcine, discontinue all vanadium process streams to lined ponds, discontinue the recycle of roaster reject.
Cap Active Calcine Impoundment	May 2001 through August 2001	Calcine was capped using multi-component cover to eliminate meteoric infiltration through calcine tailing. Substantial amount of dust control/construction water used.
Dismantle Vanadium Plant	November 2001 through May 2002	Materials removed to approved facility, surface footprint cleaned in preparation for surface regrade. Footprint regraded with limestone fines in April/May 2003
Dismantle Fertilizer Plant	November 2002 through June 2003	Materials removed to approved facility, surface footprint cleaned in preparation for surface regrade.
Reclaim Stormwater Runoff Ponds	September through October 2003	Solids and liquids removed to 10-acre pond, site regraded and reclaimed.
Reclaim 5-Acre Ponds	September through October 2004	Solids and liquids removed to 10-acre pond, east pond site regraded and reclaimed.
Regrade Scrubber Pond Cover	November 2005	Fill and regrade south of calcine cap

Note: Changes in the discharge locations of both the S-X and scrubber streams affected concentrations in both on-site and off-site wells and Finch Spring during operation.

TABLE 6-1
PROJECTED COC TRENDS BASED ON NOVEMBER 1997 THROUGH 2012 DATA

Monitor Well	MANGANESE					MOLYBDENUM				
	May 2012 Conc. (ug/l)	Projected Year Below RBC	Mn Regression Equation	Mn Coefficient of Determination	Mn Correlation Coefficient	May 2012 Conc. (ug/l)	Projected Year Below RBC	Mo Regression Equation	Mo Coefficient of Determination	Mo Correlation Coefficient
KM-2*	31	Below RBC				770	2023	$y = 2E+08e-3E-04x$	$R^2 = 0.7651$	0.87
KM-3*	510	Increasing Trend	$y = 0.6617e0.0002x$	$R^2 = 0.3575$	0.60	5500	2045	$y = 9E+06e-2E-04x$	$R^2 = 0.4717$	0.69
KM-4	69	Below RBC				1100	NE			
KM-5*	0.46	Below RBC				180	2008	$y = 17306e-1E-04x$	$R^2 = 0.4042$	0.64
KM-6	190	Close to RBC				1200	2046	$y = 268140e-1E-04x$	$R^2 = 0.5276$	0.73
KM-7	89	Below RBC				280	NE			
KM-8*	6100	Increasing Trend	$y = 1702.1e2E-05x$	$R^2 = 0.0054$	0.07	36000	>2050	$y = 5E+07e-2E-04x$	$R^2 = 0.5792$	0.76
KM-9*	5.1	Below RBC				130	Below RBC			
KM-11*	12	Below RBC				190	NE			
KM-12*	20	Below RBC				320	2018	$y = 1E+07e-3E-04x$	$R^2 = 0.9637$	0.98
KM-13*	5.8	Below RBC				180	2013	$y = 4E+07e-3E-04x$	$R^2 = 0.7942$	0.89
KM-15	35	Below RBC				450	2020	$y = 724818e-2E-04x$	$R^2 = 0.6201$	0.79
KM-16	95	Below RBC				720	2030	$y = 737568e-2E-04x$	$R^2 = 0.6551$	0.81
KM-17	6.6	Below RBC				310	2023	$y = 93636e-1E-04x$	$R^2 = 0.6324$	0.80
KM-18	33	Below RBC				340	2019	$y = 2E+06e-2E-04x$	$R^2 = 0.7467$	0.86
KM-19*	0.57	Below RBC				14	Below RBC			
Finch Spring	0.92	Below RBC				150	Below RBC	$y = 6E+06e-3E-04x$	$R^2 = 0.95$	0.97
Big Spring	0.62	Below RBC				200	2013	$y = 423527e-2E-04x$	$R^2 = 0.9369$	0.97

Shaded cell indicates exceedence of RBC

* - Point of Compliance Well

NE - Not evaluated for COC projection

Green highlight = stronger correlation to predicted future conc.

Red highlight = weaker correlation to predicted future conc.

TABLE 6-1
PROJECTED COC TRENDS BASED ON NOVEMBER 1997 THROUGH 2012 DATA

VANADIUM					
Monitor Well	May 2012 Conc. (ug/l)	Projected Year Below RBC	Regression Equation	V Coefficient of Determination	V Correlation Coefficient
KM-2*	4200	2049	$y = 4E+06e-2E-04x$	$R^2 = 0.7601$	0.87
KM-3*	2100	2069	$y = 88448e-9E-05x$	$R^2 = 0.2401$	0.49
KM-4	7200	NE			
KM-5*	1600	2040	$y = 129846e-1E-04x$	$R^2 = 0.462$	0.68
KM-6	4200	2099	$y = 74751e-7E-05x$	$R^2 = 0.3558$	0.60
KM-7	2400	NE			
KM-8*	13000	Increasing Trend	$y = 3790.8e4E-05x$	$R^2 = 0.0257$	0.16
KM-9*	330	2015	$y = 472998e-2E-04x$	$R^2 = 0.932$	0.97
KM-11*	8.4	Below RBC			
KM-12*	480	2021	$y = 636232e-2E-04x$	$R^2 = 0.967$	0.98
KM-13*	440	2020	$y = 82384e-1E-04x$	$R^2 = 0.8725$	0.93
KM-15	820	2033	$y = 124096e-1E-04x$	$R^2 = 0.8507$	0.92
KM-16	2200	2058	$y = 201653e-1E-04x$	$R^2 = 0.7445$	0.86
KM-17	14	Below RBC			
KM-18	590	2025	$y = 249975e-1E-04x$	$R^2 = 0.9213$	0.96
KM-19*	95	Below RBC			
Finch Spring	49				
Big Spring	3.4				

Shaded cell indicates exceedence of RBC

* - Point of Compliance Well

NE - Not evaluated for COC projection

Green highlight = stronger correlation to predicted future conc.

Red highlight = weaker correlation to predicted future conc.

TABLE 6-2
PROJECTED COC TREND
BASED ON MAY 2004 THROUGH 2012 DATA

	MANGANESE						MOLYBDENUM				
Monitor Well	May 2012 Conc. (ug/l)	Mn Projected Year Below RBC	Mn Regression Equation	Mn Coefficient of Determination	Mn Correlation Coefficient	May 2012 Conc. (ug/l)	Mo Projected Year Below RBC	Mo Regression Equation	Mo Coefficient of Determination	Mo Correlation Coefficient	
KM-2*	31	Below RBC				770	2029	y = 5E+06e-2E-04x	R² = 0.7496	0.87	
KM-3*	510	Increasing Trend	y = 42.65e7E-05x	R² = 0.3222	0.57	5500	>2100	y = 207822e-9E-05x	R² = 0.6382	0.80	
KM-4	69	Below RBC				1100	NE				
KM-5*	0.46	Below RBC				180	2047	y = 409.35e-2E-05x	R² = 0.0105	0.10	
KM-6	190	Below RBC				1200	2089	y = 17911e-7E-05x	R² = 0.1387	0.37	
KM-7	89	Below RBC				280	NE				
KM-8*	6100	Increasing Trend	y = 0.0047e0.0003x	R² = 0.4259	0.65	36000	Increasing Trend	y = 8082.4e4E-05x	R² = 0.0308	0.18	
KM-9*	5.1	Below RBC				130	Below RBC				
KM-11*	12	Below RBC				190	NE				
KM-12*	20	Below RBC				320	2017	y = 2E+07e-3E-04x	R² = 0.9643	0.98	
KM-13*	5.8	Below RBC				180	2014	y = 133980e-2E-04x	R² = 0.3964	0.63	
KM-15	35	Below RBC				450	2060	y = 2850.8e-5E-05x	R² = 0.0574	0.24	
KM-16	95	Below RBC				720	2073	y = 8786.3e-6E-05x	R² = 0.1316	0.36	
KM-17	6.6	Below RBC				310	2019	y = 470627e-2E-04x	R² = 0.7464	0.86	
KM-18	33	Below RBC				340	2040	y = 33310e-1E-04x	R² = 0.3213	0.57	
KM-19*	0.57	Below RBC				14	Below RBC				

Shaded cell indicates exceedence of RBC

* - Point of Compliance Well

NE - Not evaluated for COC projection

Green highlight = stronger correlation to predicted future conc.

Red highlight = weaker correlation to predicted future conc.

TABLE 6-2
PROJECTED COC TREND
BASED ON MAY 2004 THROUGH 2012 DATA

	VANADIUM				
Monitor Well	May 2012 Conc. (ug/l)	V Projected Year Below RBC	V Regression Equation	V Coefficient of Determination	V Correlation Coefficient
KM-2*	4200	>2100	y = 16548e-3E-05x	R ² = 0.1391	0.37
KM-3*	2100	2070	y = 101799e-9E-05x	R ² = 0.1078	0.33
KM-4	7200	NE			
KM-5*	1600	>2100 or increasing	y = 715.91e1E-05x	R ² = 0.0042	0.06
KM-6	4200	>2100	y = 8230.2e-2E-05x	R ² = 0.0099	0.10
KM-7	2400	NE			
KM-8*	13000	2065	y = 1E+07e-2E-04x	R ² = 0.3406	0.58
KM-9*	330	2019	y = 38812e-1E-04x	R ² = 0.8052	0.90
KM-11*	8.4	Below RBC			
KM-12*	480	2020	y = 1E+06e-2E-04x	R ² = 0.9515	0.98
KM-13*	440	2029	y = 11903e-8E-05x	R ² = 0.6749	0.63
KM-15	820	2059	y = 8952.2e-6E-05x	R ² = 0.447	0.67
KM-16	2200	>2100	y = 13099e-4E-05x	R ² = 0.1806	0.36
KM-17	14	Below RBC			
KM-18	590	2034	y = 36585e-1E-04x	R ² = 0.7847	0.89
KM-19*	95	Below RBC			

Shaded cell indicates exceedence of RBC

* - Point of Compliance Well

NE - Not evaluated for COC projection

Green highlight = stronger correlation to predicted future conc.

Red highlight = weaker correlation to predicted future conc.

FIGURES



KEY

KM-2
○ 5988.14
WELL LOCATION AND
WATER LEVEL ELEVATION.
ASTERISK DENOTES
JUNE WATER LEVEL

○ EV-3
5919.86



SCALE (feet)

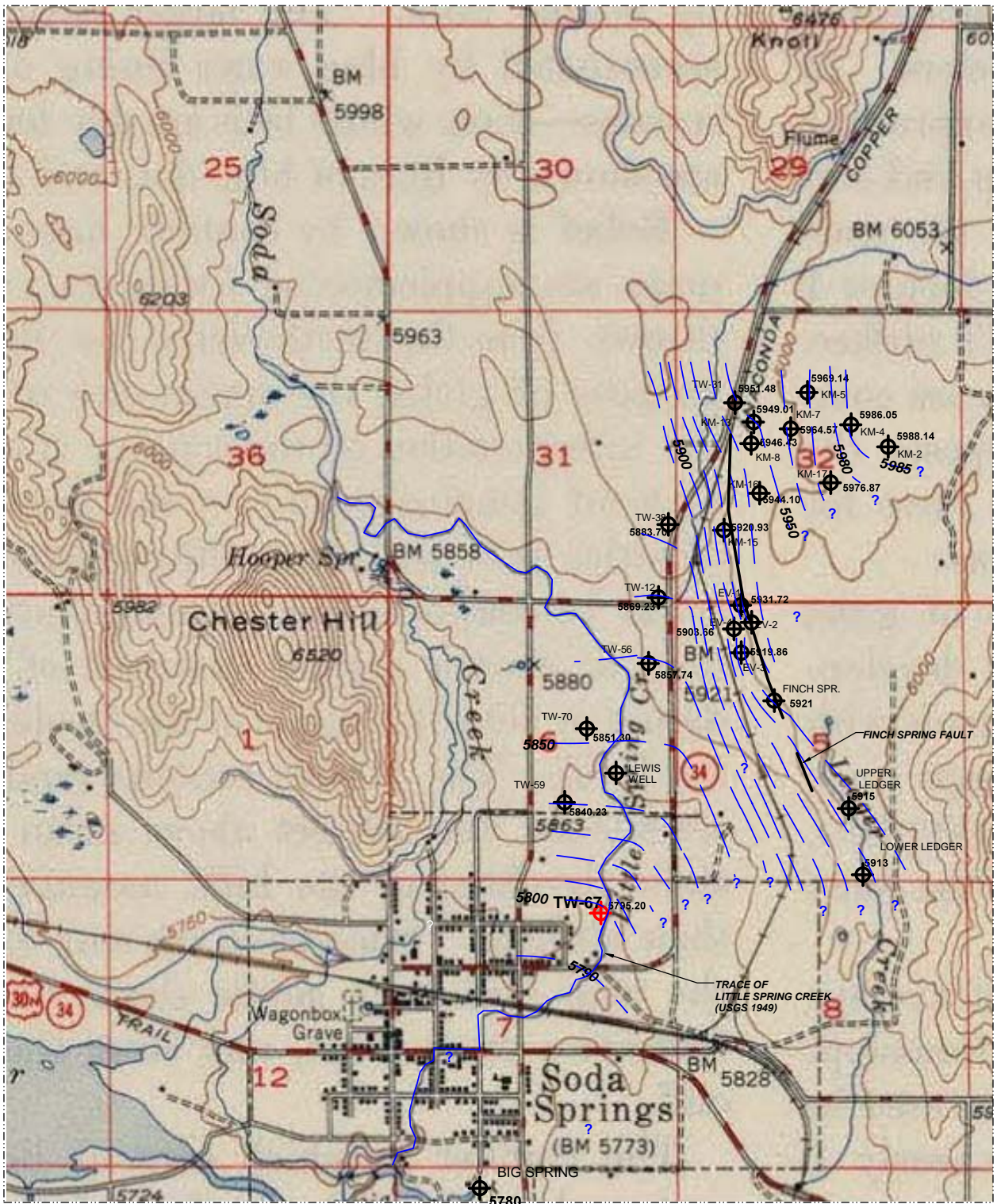
NOTE: CONTOURS BASED ON GROUND
WATER LEVELS IN SHALLOW WELLS

2013 ANNUAL COMPREHENSIVE
GROUND WATER REPORT

CONTOUR OF GROUND WATER LEVEL ELEVATIONS MAY 2012

GREENFIELD TRUST
SODA SPRINGS, IDAHO

FIGURE 1-2



KEY

5790
WATER LEVEL CONTOUR
AND ELEVATION

5988.14
KM-2
WELL LOCATION AND
ELEVATION - MONSANTO
AND EVERGREEN
JUNE MEASUREMENT

0 1000

SCALE (feet)

REFERENCES: GOLDER 2012,
CITY OF SODA SPRINGS, 2012
USGS 1:62500 SCALE MAP 1949

2013 ANNUAL COMPREHENSIVE
GROUND WATER REPORT

CONTOUR OF REGIONAL GROUND WATER LEVEL ELEVATIONS MAY TO JUNE 2012

GREENFIELD TRUST
SODA SPRINGS, IDAHO

FIGURE 1-2a

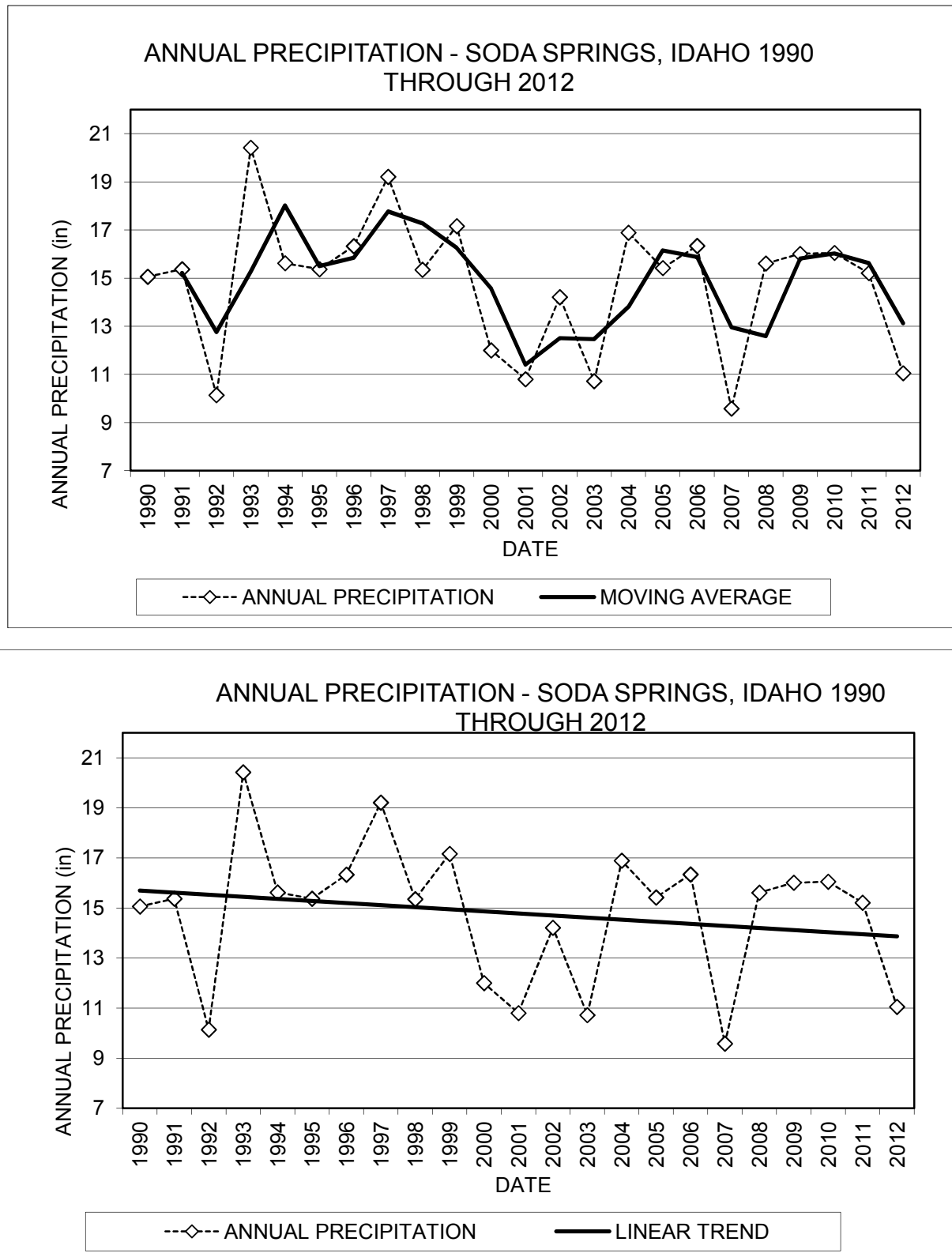


FIGURE 2-2

WATER LEVELS VERSUS TIME **TRUST ON-SITE WELLS** **FOLLOWING LSE AND POND RECLAMATION**

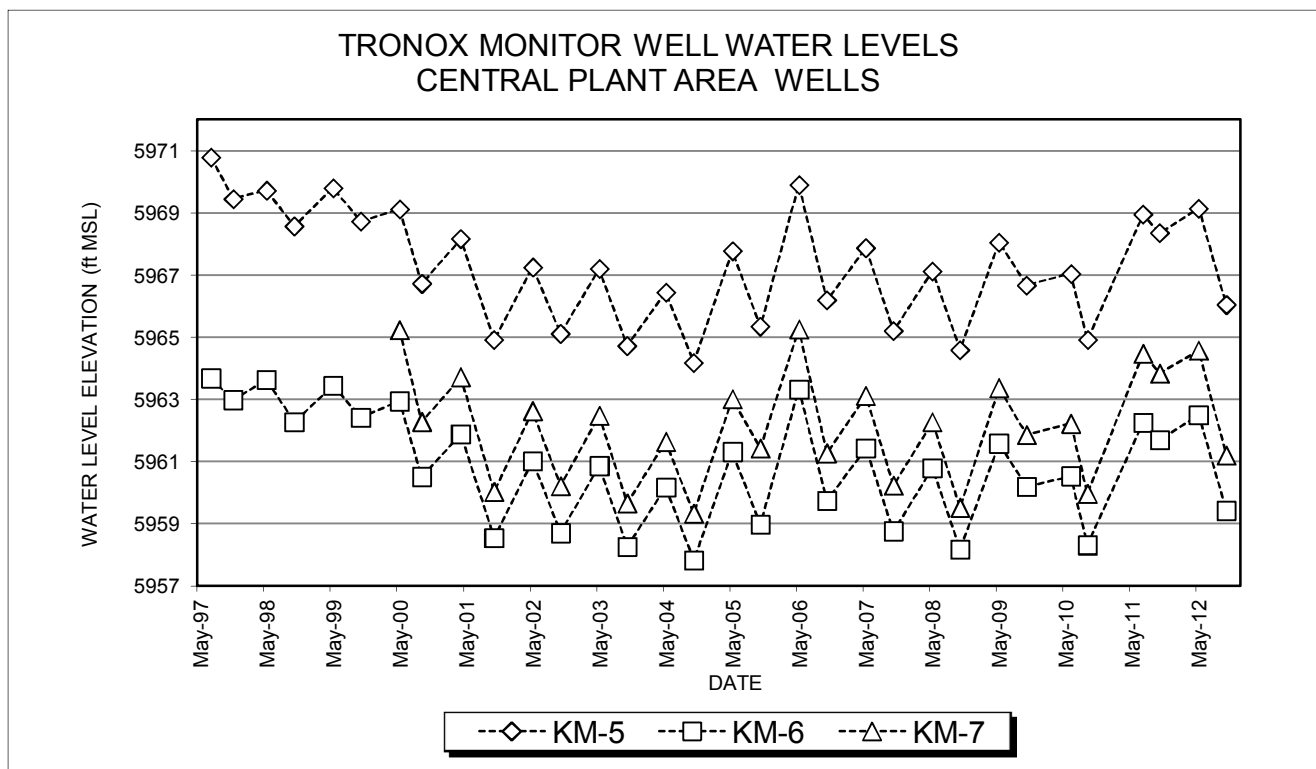
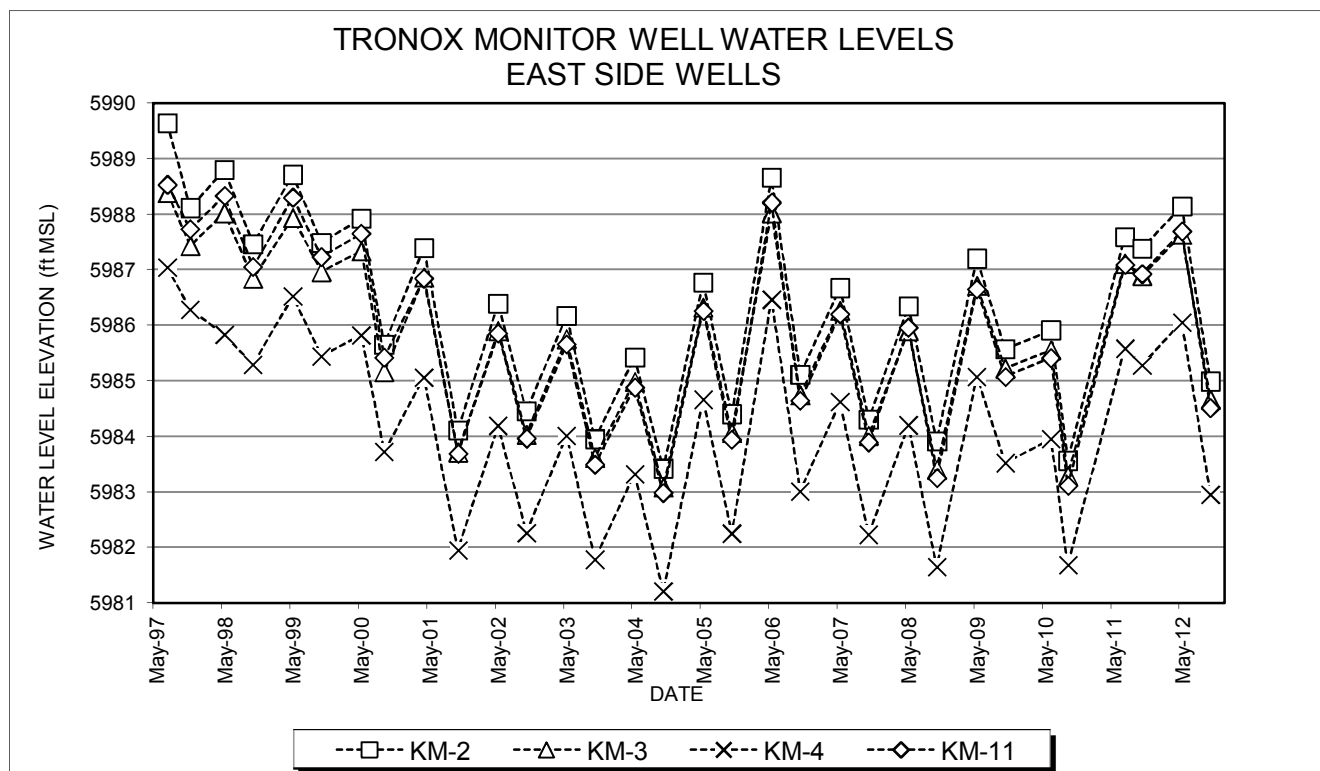


FIGURE 2-3a

WATER LEVELS VERSUS TIME **TRUST WELLS** **FOLLOWING LSE AND POND RECLAMATION**

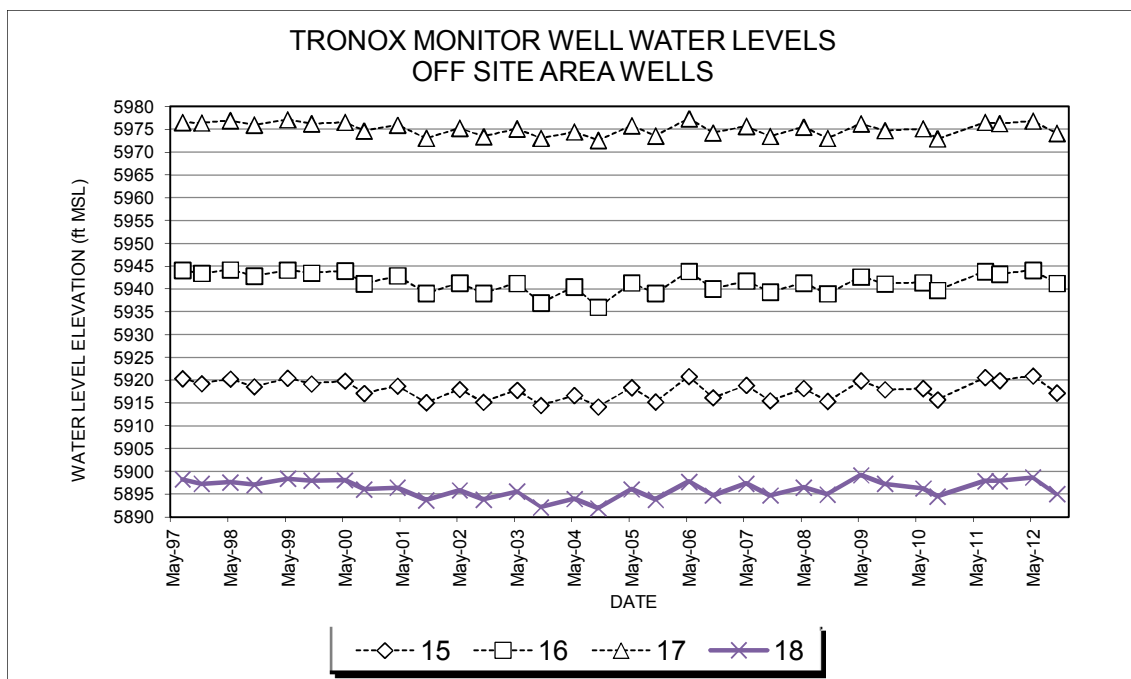
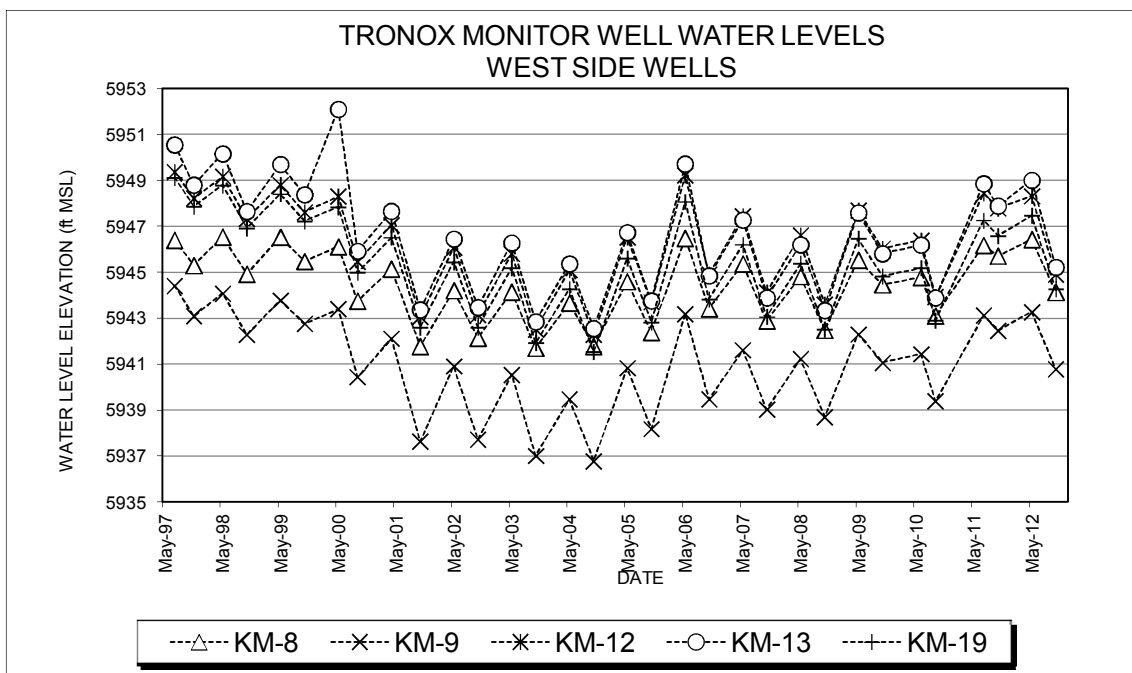
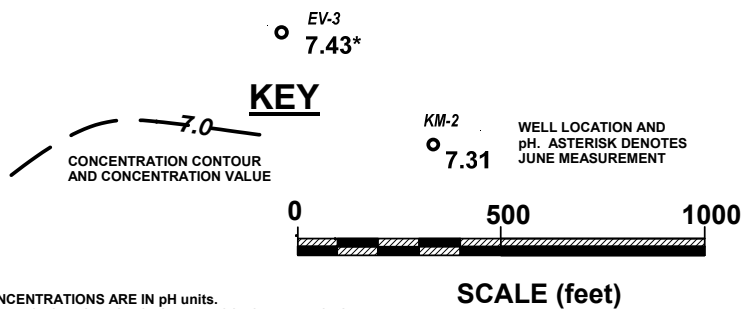
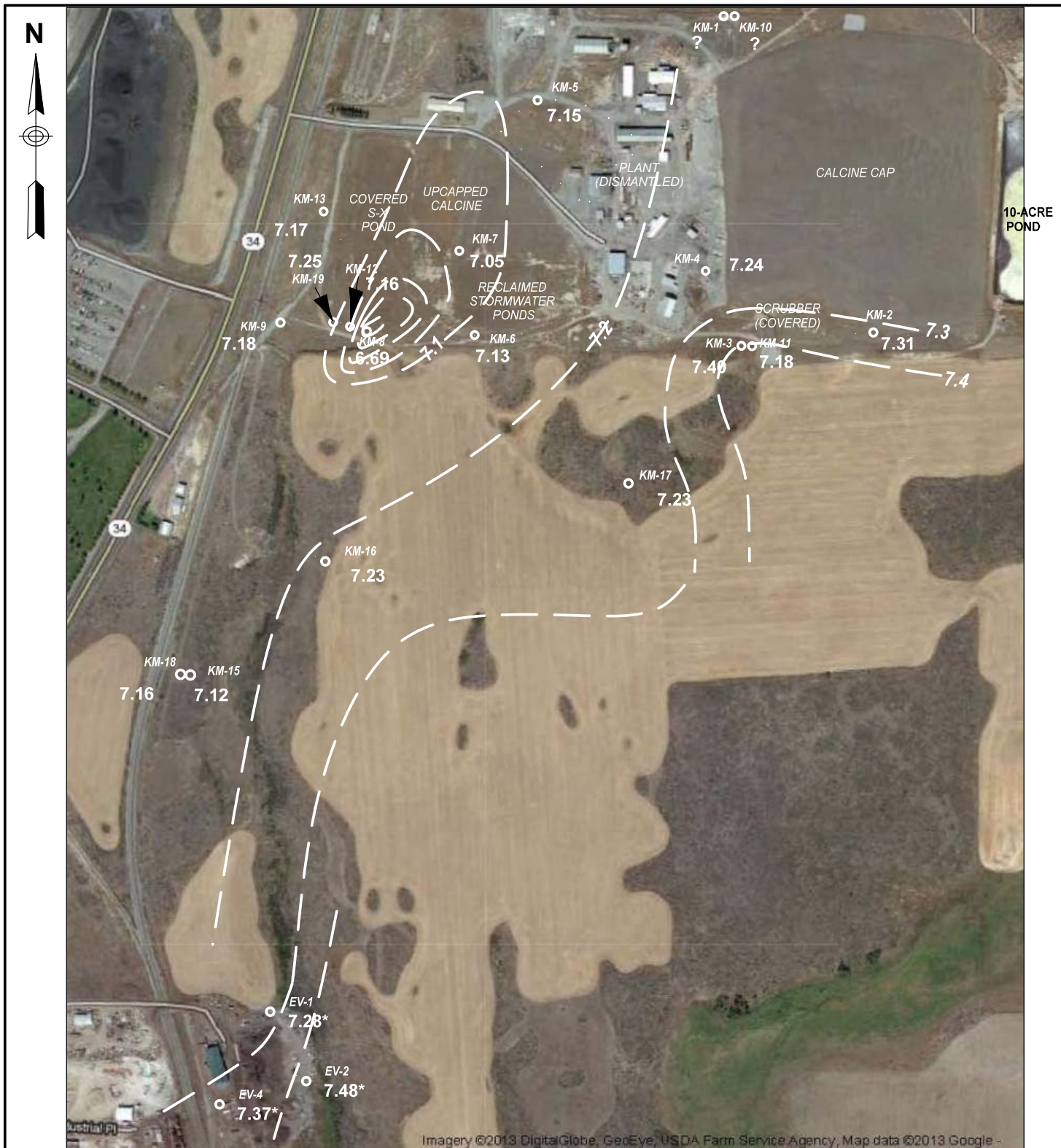


FIGURE 2-3b



NOTE: CONCENTRATIONS ARE IN pH units.
CONCENTRATIONS BASED ON OBSERVED CONCENTRATIONS
IN SHALLOW AQUIFER.

2013 ANNUAL COMPREHENSIVE
GROUND WATER REPORT

CONTOUR OF pH IN GROUND WATER MAY 2012

GREENFIELD TRUST
SODA SPRINGS, IDAHO

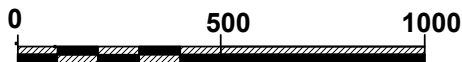
FIGURE 4-1



EV-3
570*

KEY

KM-2
84
WELL LOCATION AND
CONCENTRATION.
ASTERISK DENOTES
JUNE MEASUREMENT



SCALE (feet)

2013 ANNUAL COMPREHENSIVE
GROUND WATER REPORT

CONTOUR OF TDS IN GROUND WATER MAY 2012

GREENFIELD TRUST
SODA SPRINGS, IDAHO

FIGURE 4-2

NOTE: CONCENTRATIONS ARE IN MG/L.
OBSERVATIONS BASED ON CONCENTRATIONS
IN SHALLOW AQUIFER.

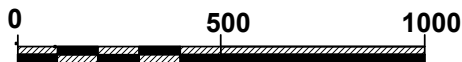


Imagery ©2013 DigitalGlobe, GeoEye, USDA Farm Service Agency, Map data ©2013 Google -

EV-3
29*

KEY

KM-2
84
WELL LOCATION AND
CONCENTRATION.
ASTERISK DENOTES
JUNE MEASUREMENT



SCALE (feet)

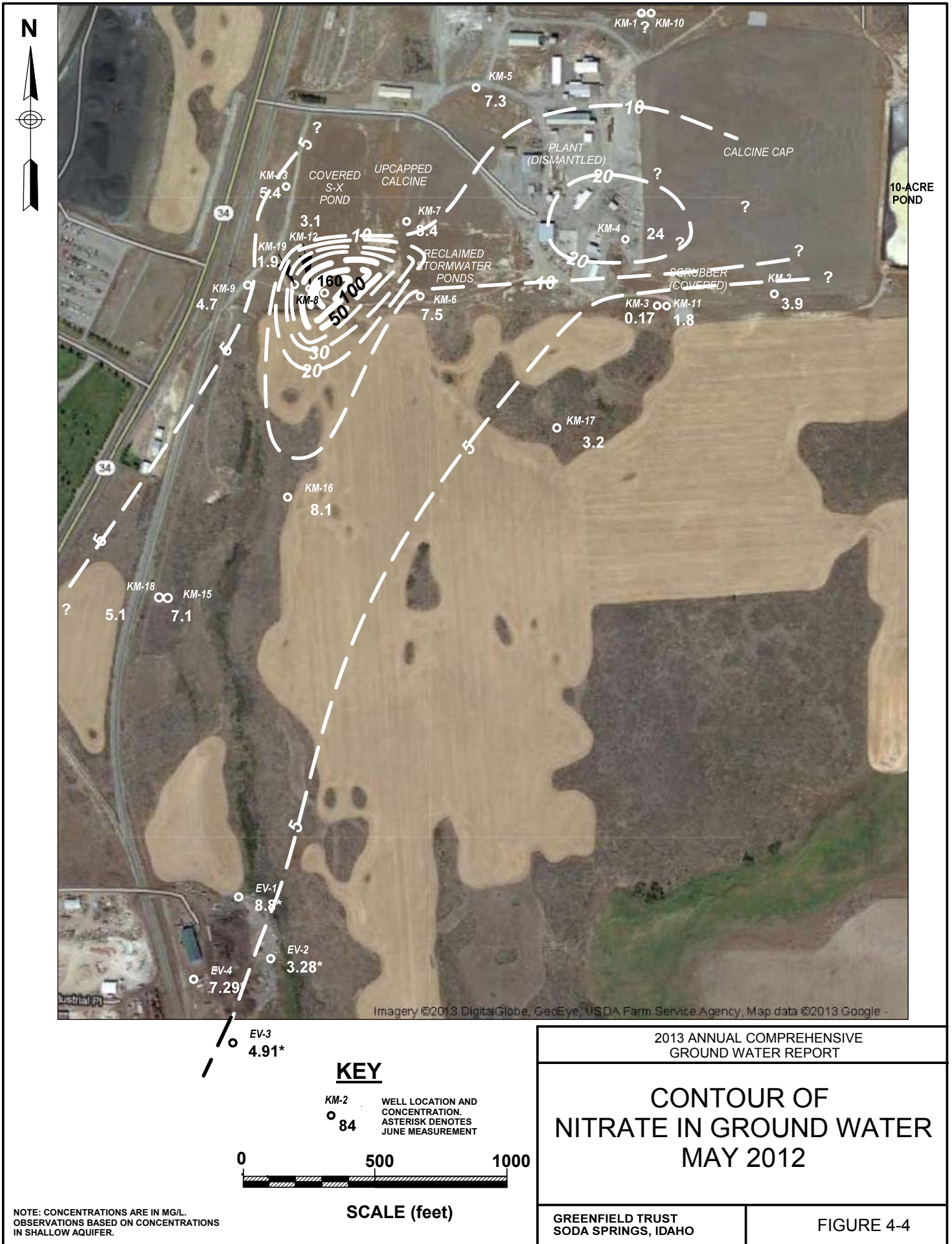
NOTE: CONCENTRATIONS ARE IN MG/L.
CONCENTRATIONS BASED ON OBSERVED CONCENTRATIONS
IN SHALLOW AQUIFER.

2013 ANNUAL COMPREHENSIVE
GROUND WATER REPORT

CONTOUR OF CHLORIDE IN GROUND WATER MAY 2012

GREENFIELD TRUST
SODA SPRINGS, IDAHO

FIGURE 4-3





EV-3

67*

KEY

KM-2

160

WELL LOCATION AND
CONCENTRATION.
ASTERISK DENOTES
JUNE MEASUREMENT

CONCENTRATION
CONTOUR AND VALUE



SCALE (feet)

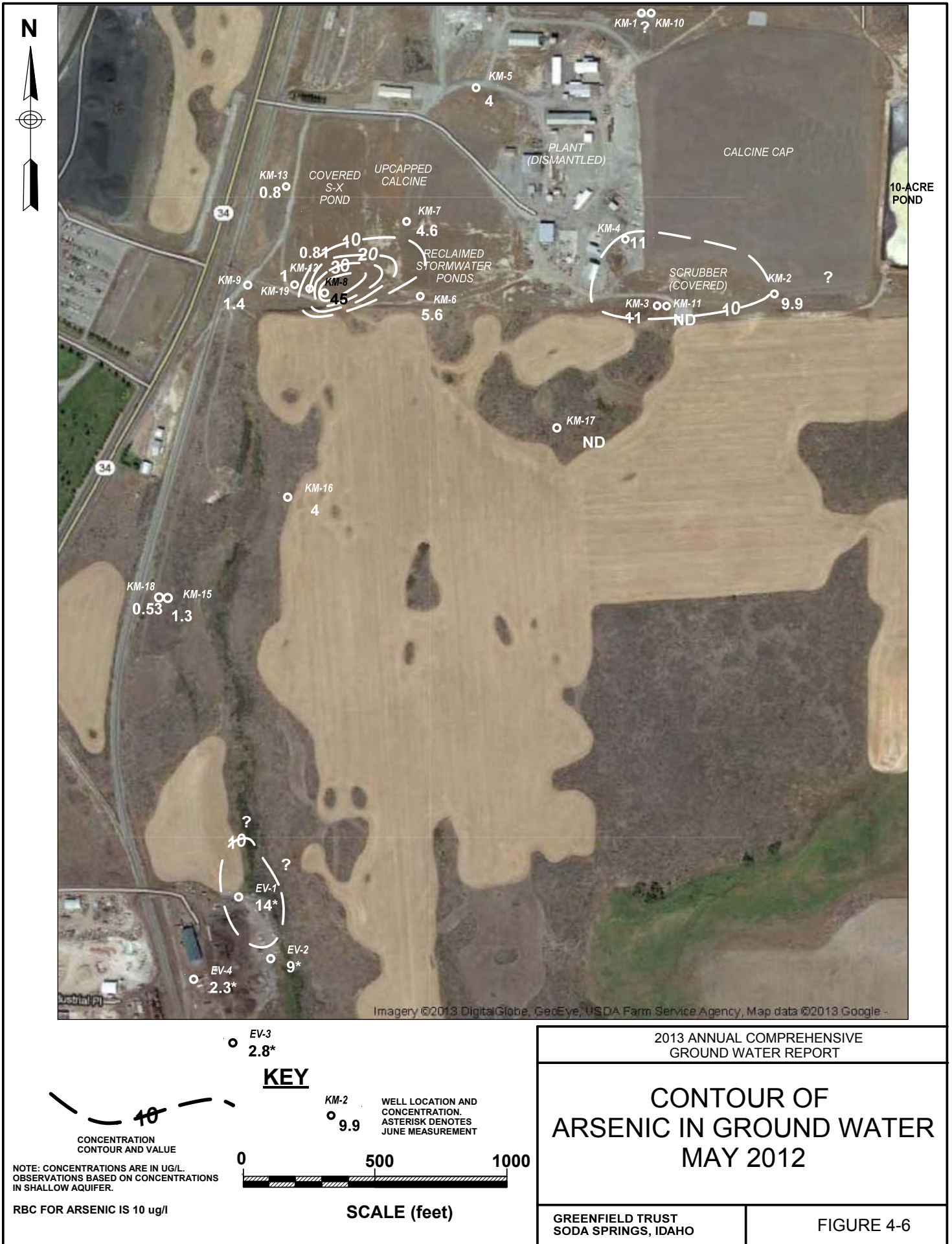
NOTE: CONCENTRATIONS ARE IN MG/L.
OBSERVATIONS BASED ON CONCENTRATIONS
IN SHALLOW AQUIFER.

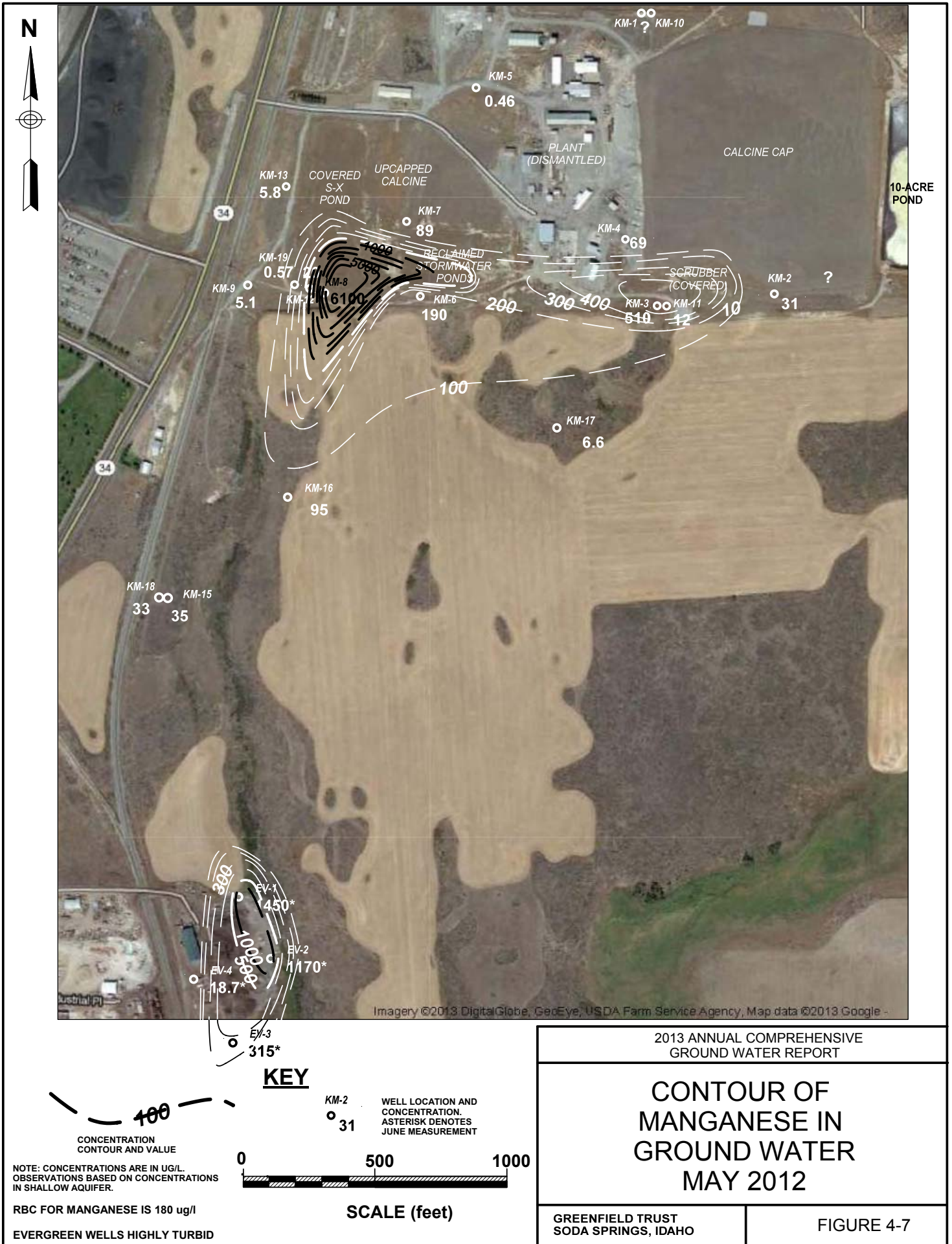
2013 ANNUAL COMPREHENSIVE
GROUND WATER REPORT

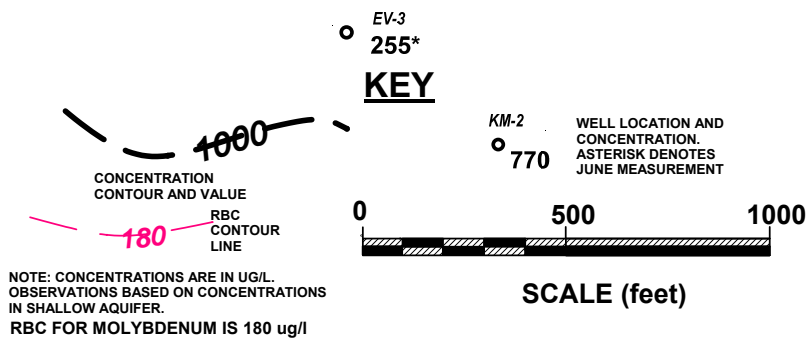
CONTOUR OF SULFATE IN GROUND WATER MAY 2012

GREENFIELD TRUST
SODA SPRINGS, IDAHO

FIGURE 4-5







2013 ANNUAL COMPREHENSIVE
GROUND WATER REPORT

CONTOUR OF MOLYBDENUM IN GROUND WATER MAY 2012

GREENFIELD TRUST
SODA SPRINGS, IDAHO

FIGURE 4-8



APPROXIMATE LOCATION OF
MOLYBDENUM EXCEEDING
RISK LEVELS IN SHALLOW
GROUND WATER
MAY TO JUNE 2012

FIGURE 4-8a

~~180~~

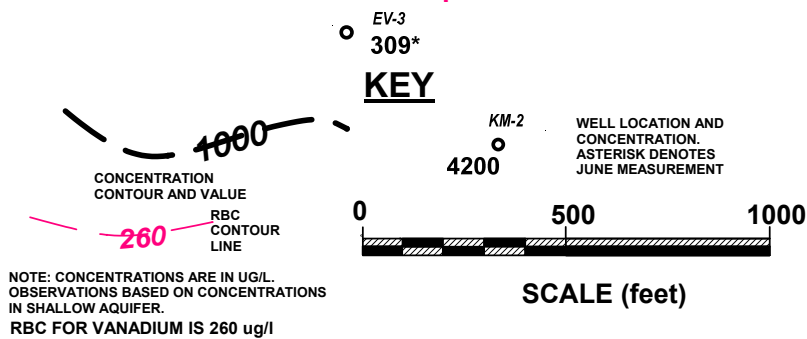
MOLYBDENUM ISOPLETH
OF RISK BASED CONCENTRATION
AND VALUE

WELL LOCATION AND
MOLYBDENUM VALUE
MONSANTO AND EVERGREEN
ARE JUNE CONCENTRATION

0 500 1000

SCALE (feet)

REFERENCES: GOLDER 2012,
CITY OF SODA SPRINGS, 2012
USGS 1:62500 SCALE MAP 1949



2013 ANNUAL COMPREHENSIVE
GROUND WATER REPORT

CONTOUR OF VANADIUM IN GROUND WATER MAY 2012


GREENFIELD TRUST
SODA SPRINGS, IDAHO

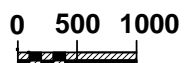
FIGURE 4-9



KEY

 260
VANADIUM ISOPLETH
OF RISK BASED CONCENTRATION
AND VALUE

 4200
KM-2
WELL LOCATION AND
VANADIUM VALUE
MONSANTO AND EVERGREEN
ARE JUNE CONCENTRATION

0 500 1000

SCALE (feet)

REFERENCES: GOLDER 2012,
CITY OF SODA SPRINGS, 2012
USGS 1:62500 SCALE MAP 1949

2013 ANNUAL COMPREHENSIVE
GROUND WATER REPORT

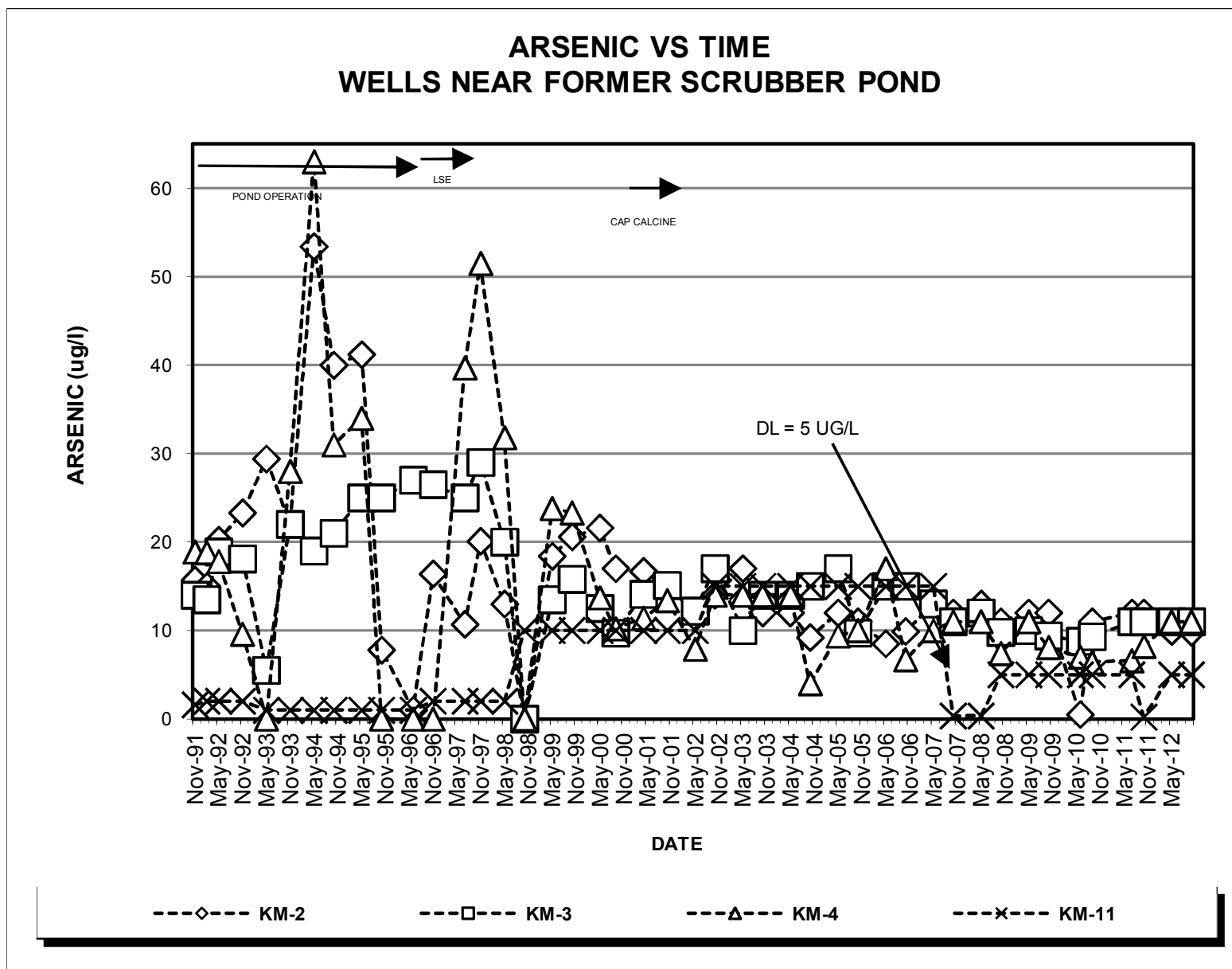
APPROXIMATE LOCATION OF
VANADIUM EXCEEDING
RISK LEVELS IN SHALLOW
GROUND WATER
MAY TO JUNE 2012

GREENFIELD TRUST
SODA SPRINGS, IDAHO

FIGURE 4-9a

APPENDIX A

**GRAPHS OF GROUND AND SURFACE WATER
QUALITY VERSUS TIME**

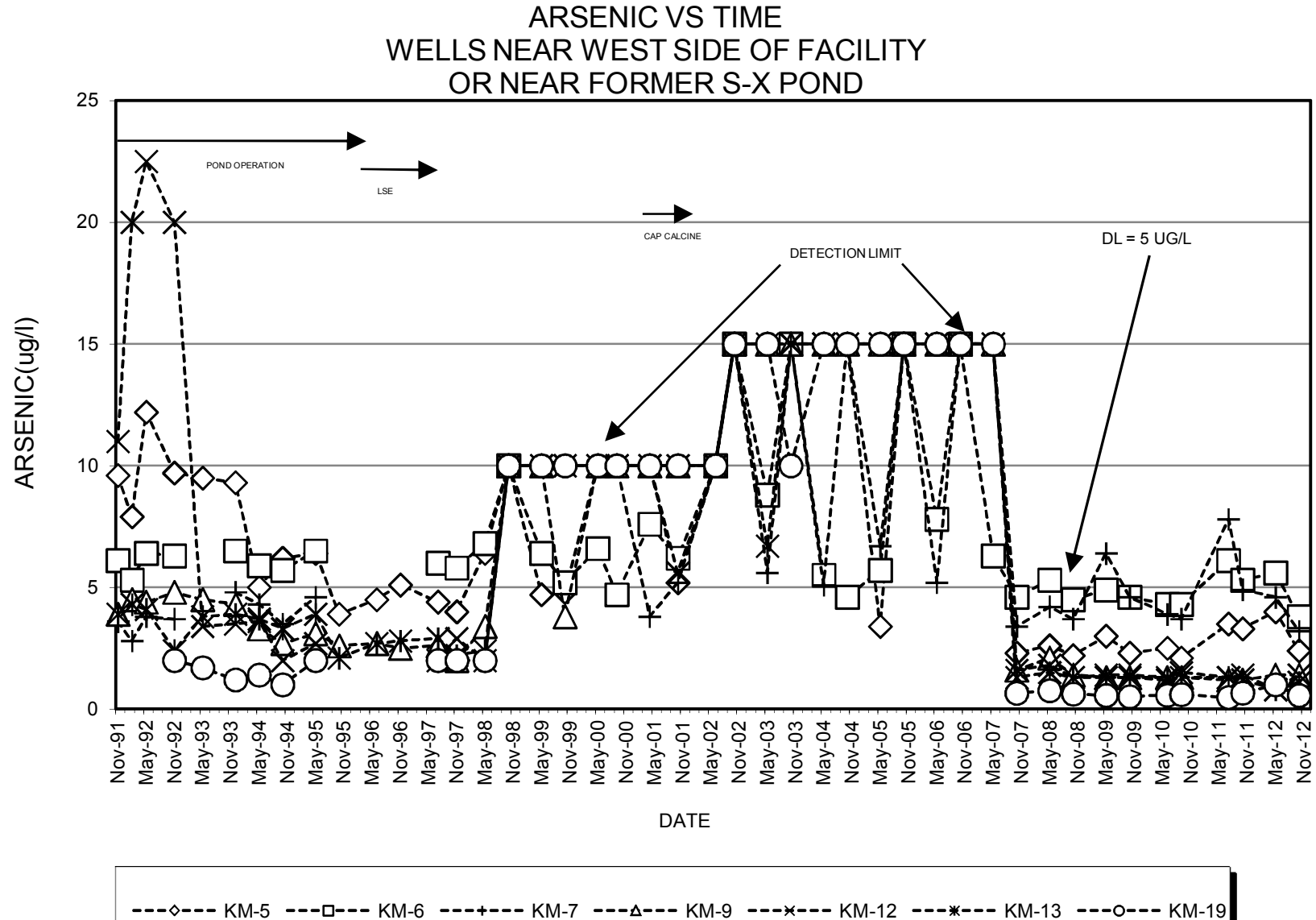


RBC FOR ARSENIC IS 10 ug/l

KM-2, KM-3, KM-11 ARE POC WELLS

VALUES LESS THAN DETECTION ARE PLOTTED AT DETECTION LIMIT

ARSENIC DETECTION LIMIT AT 10 to 15 UG/L 1999 THROUGH 2007

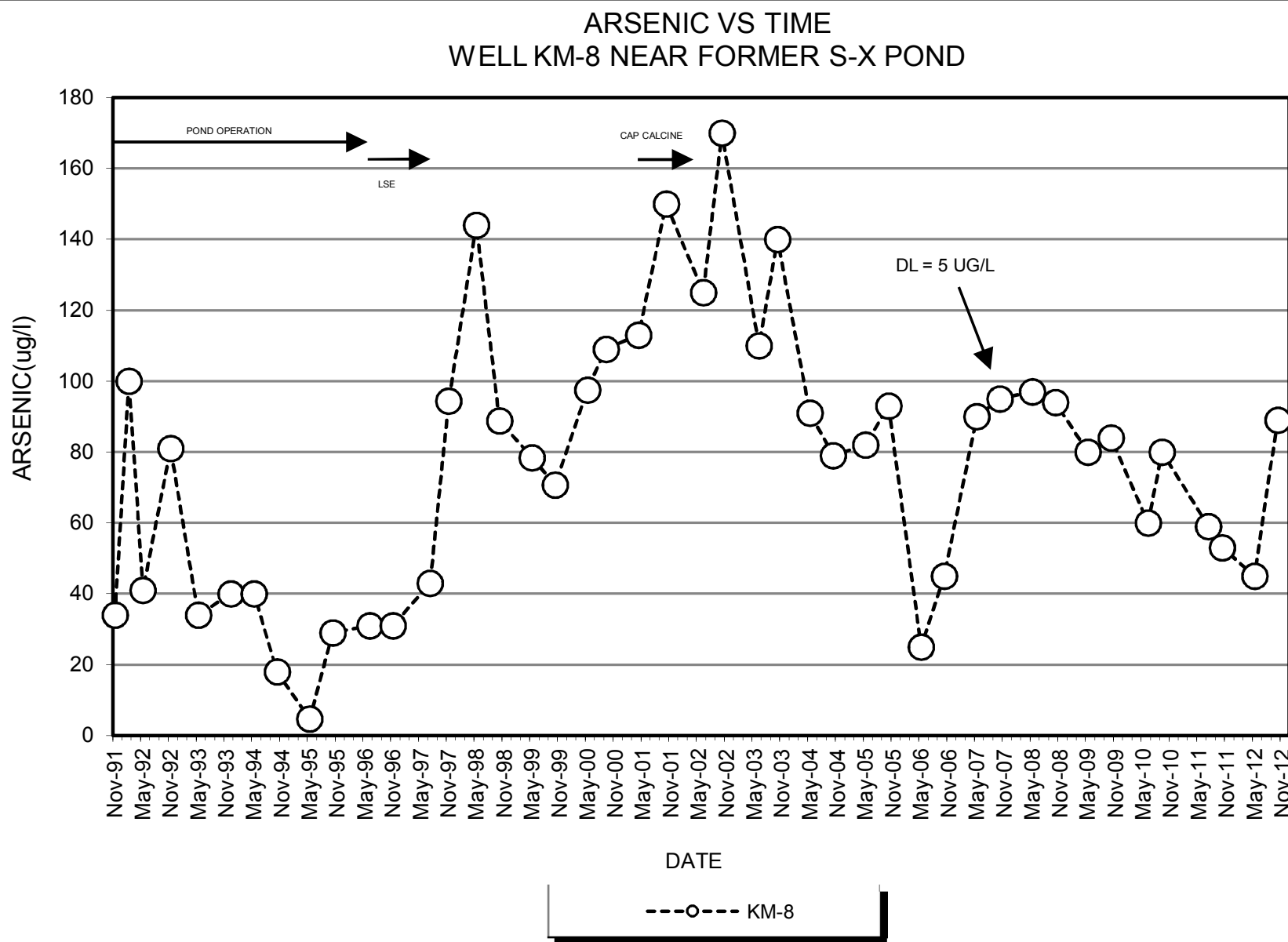


RBC FOR ARSENIC IS 10 ug/l

KM-5, KM-9, KM-12, KM-13, KM-19 ARE POC WELLS

VALUES LESS THAN DETECTION ARE PLOTTED AT THE DETECTION LIMIT

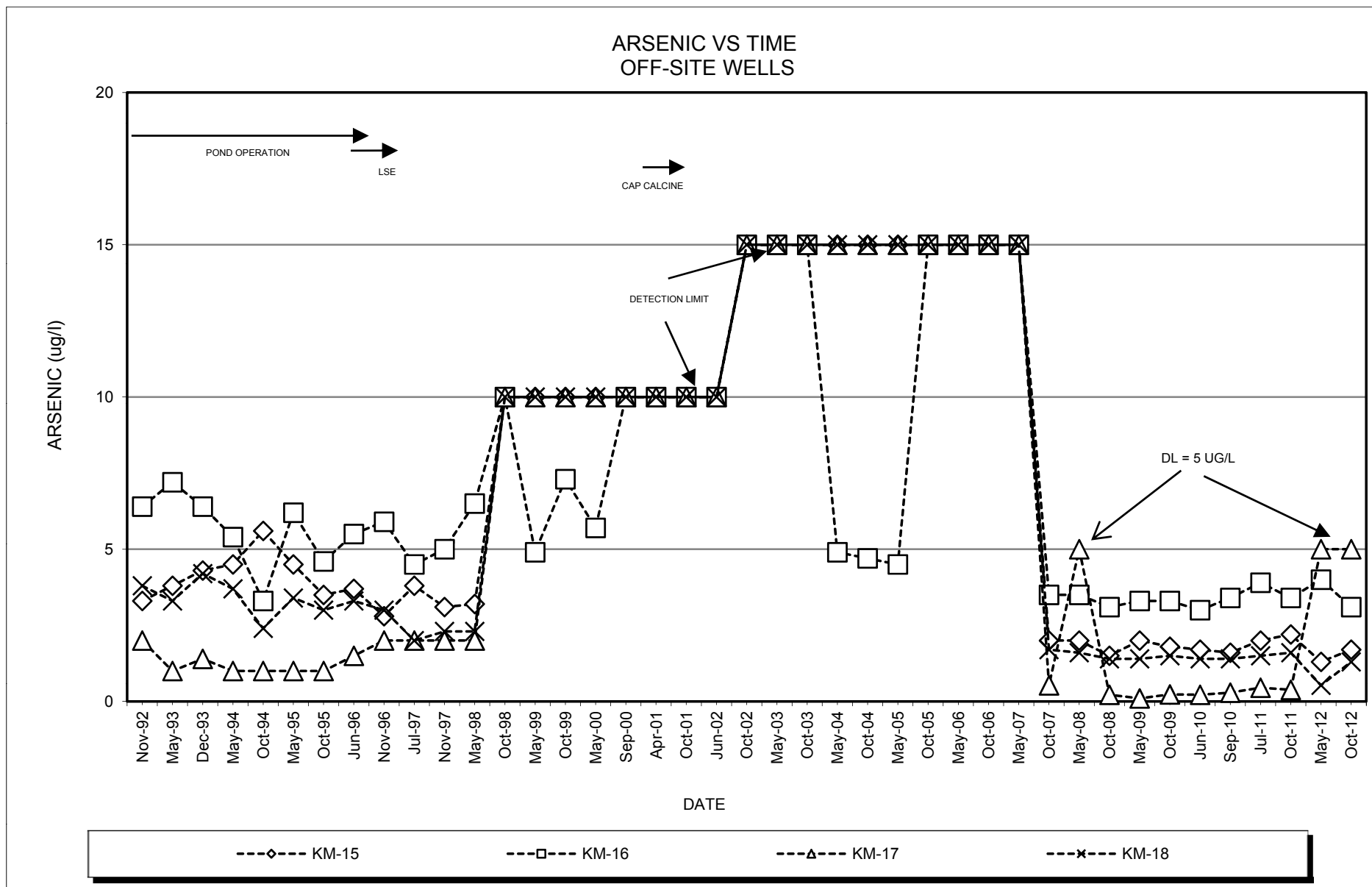
ARSENIC IS LESS THAN DETECTION OR REPORTING LIMIT IN ALL WELLS DURING 2003 through May 2007



RBC FOR ARSENIC IS 10 ug/l

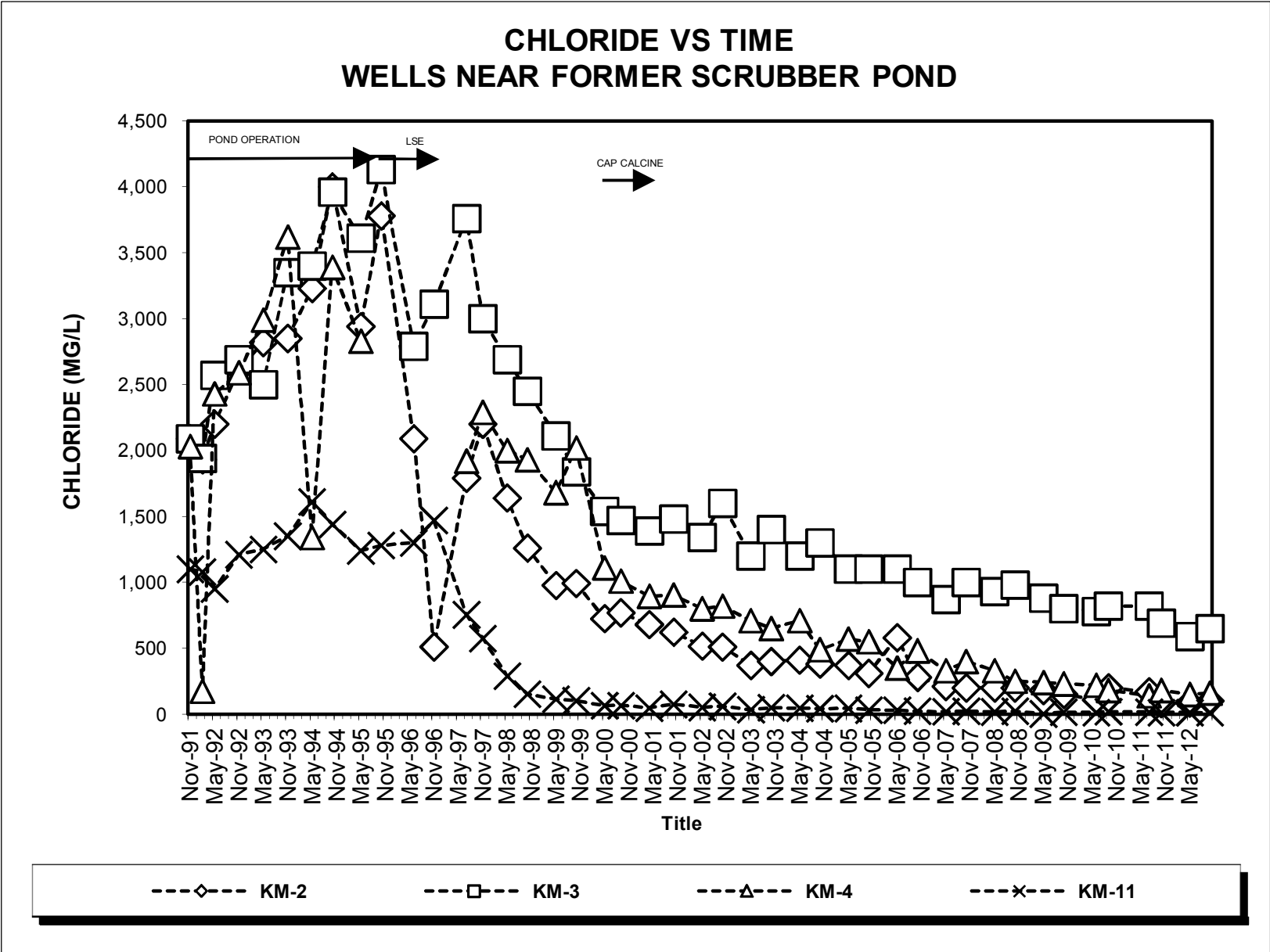
KM-8 IS A POC WELL

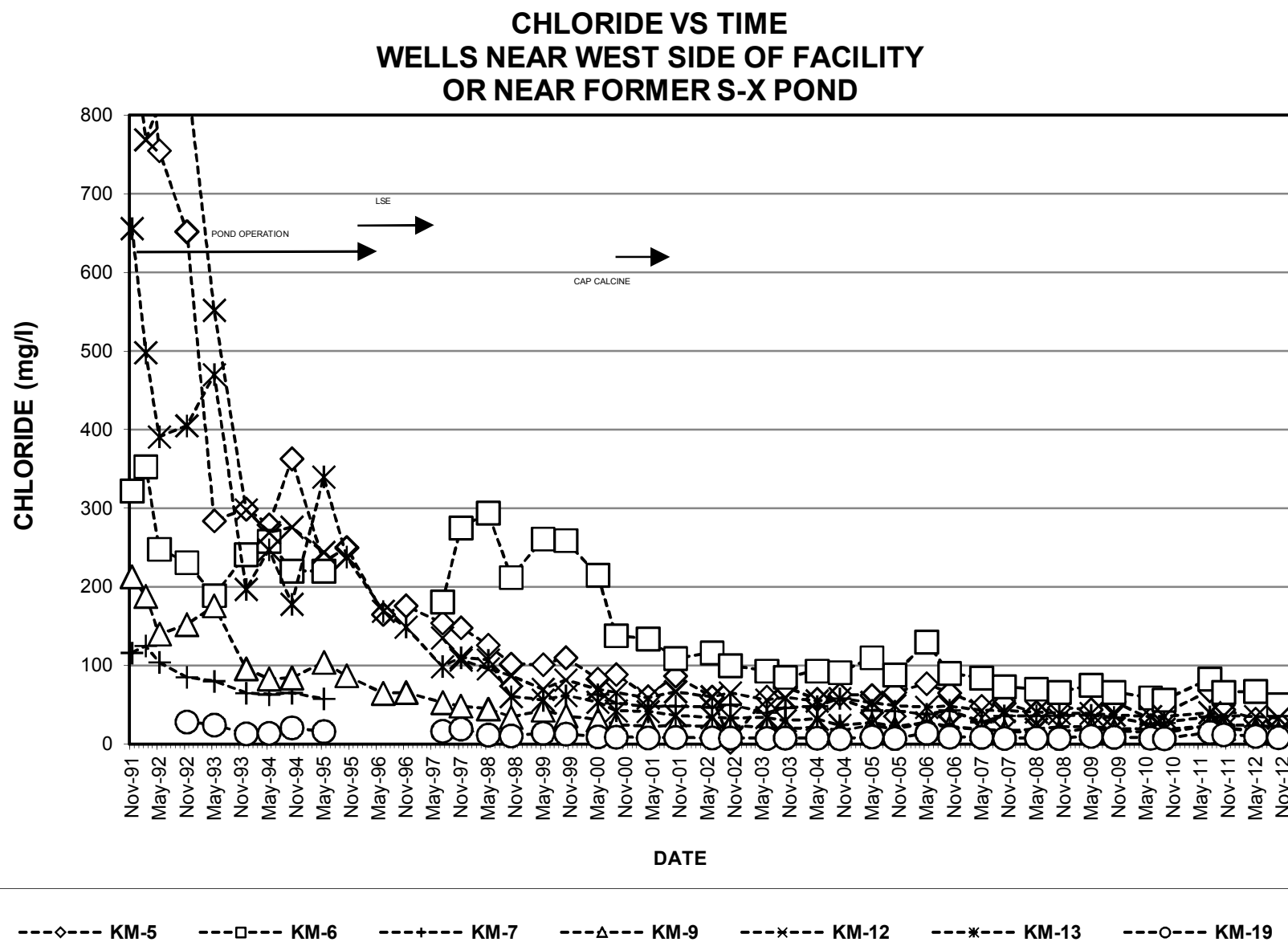
VALUES LESS THAN DETECTION ARE PLOTTED AT THE DETECTION LIMIT

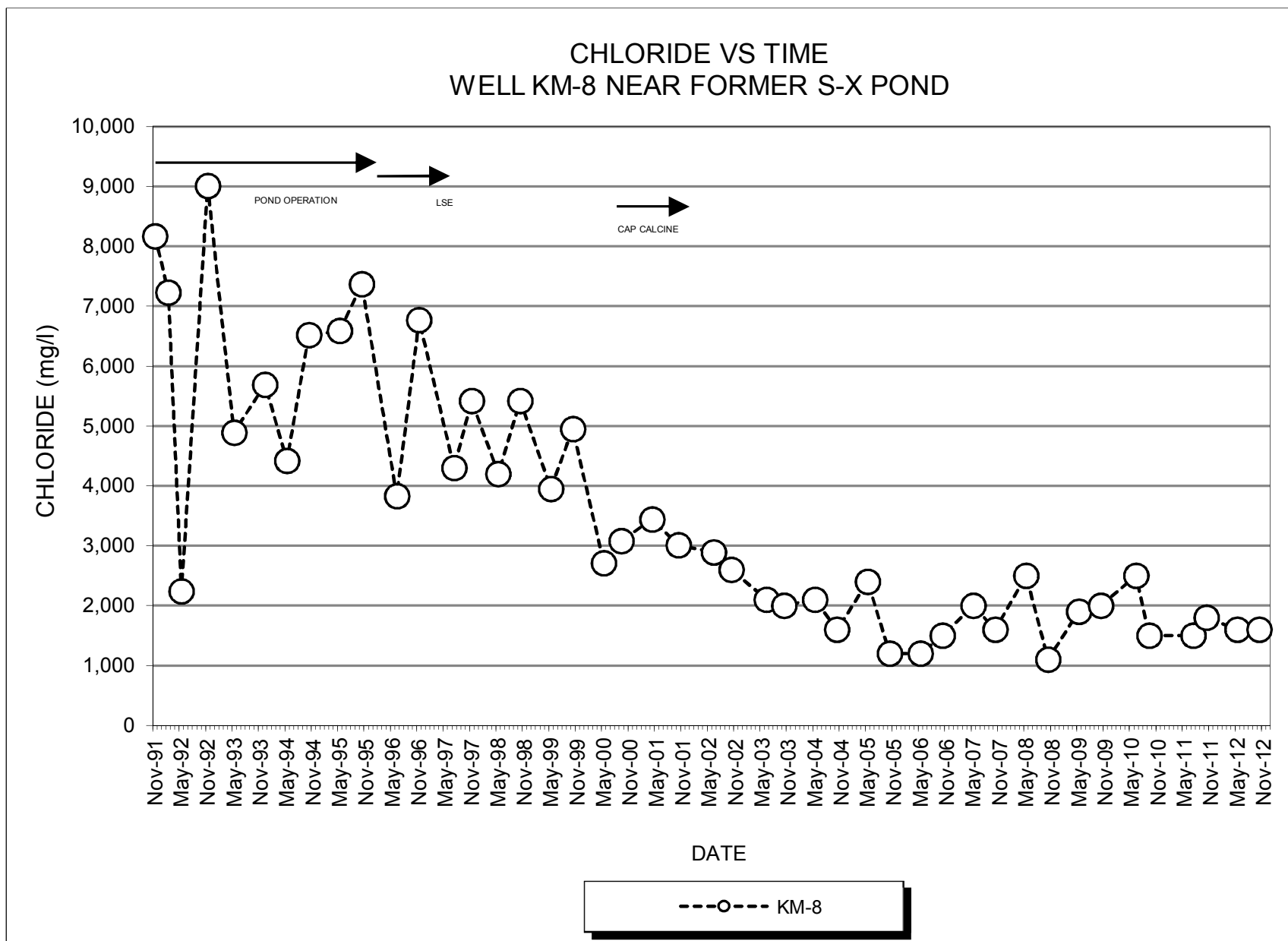


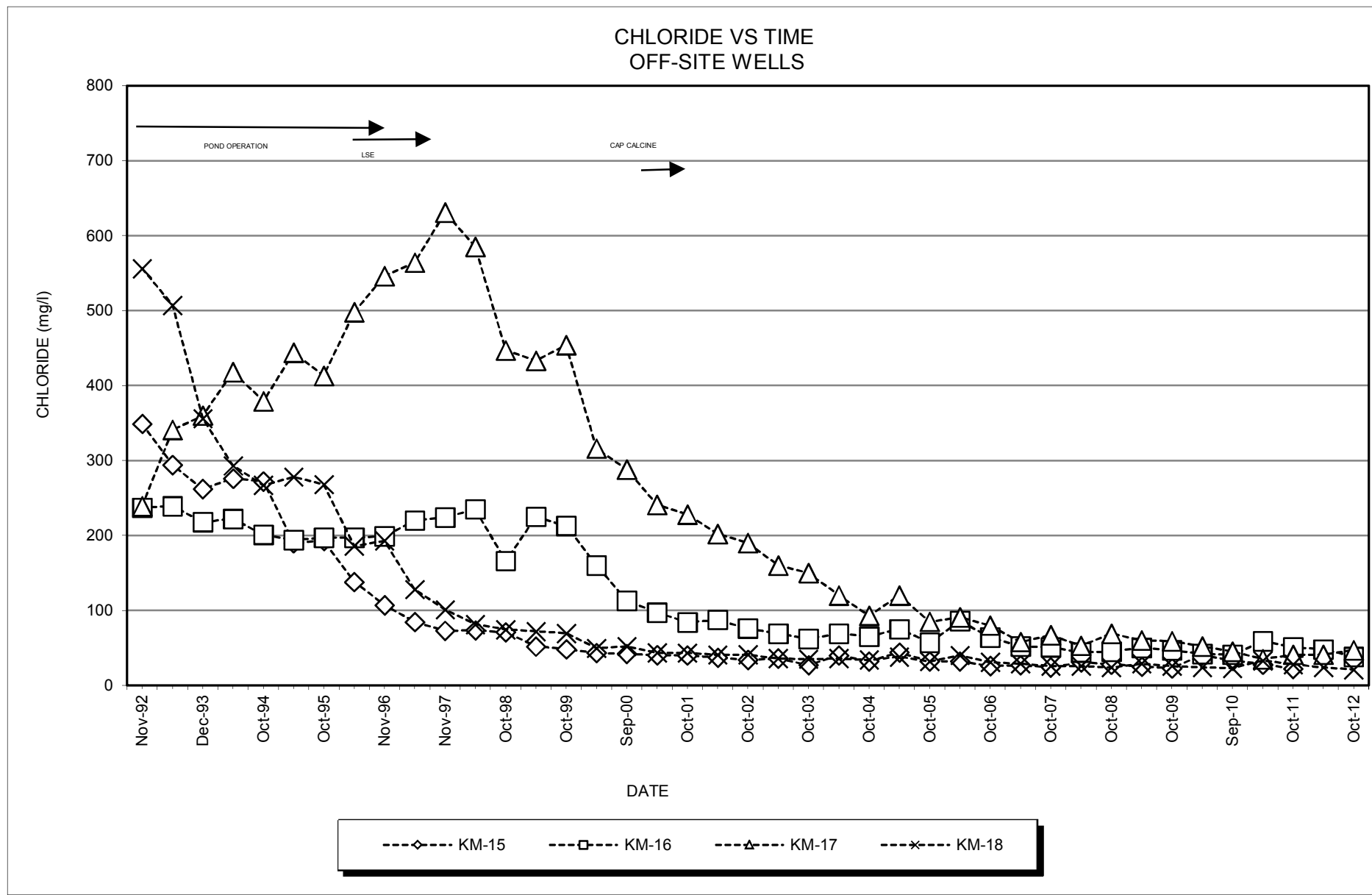
RBC = 10 ug/l

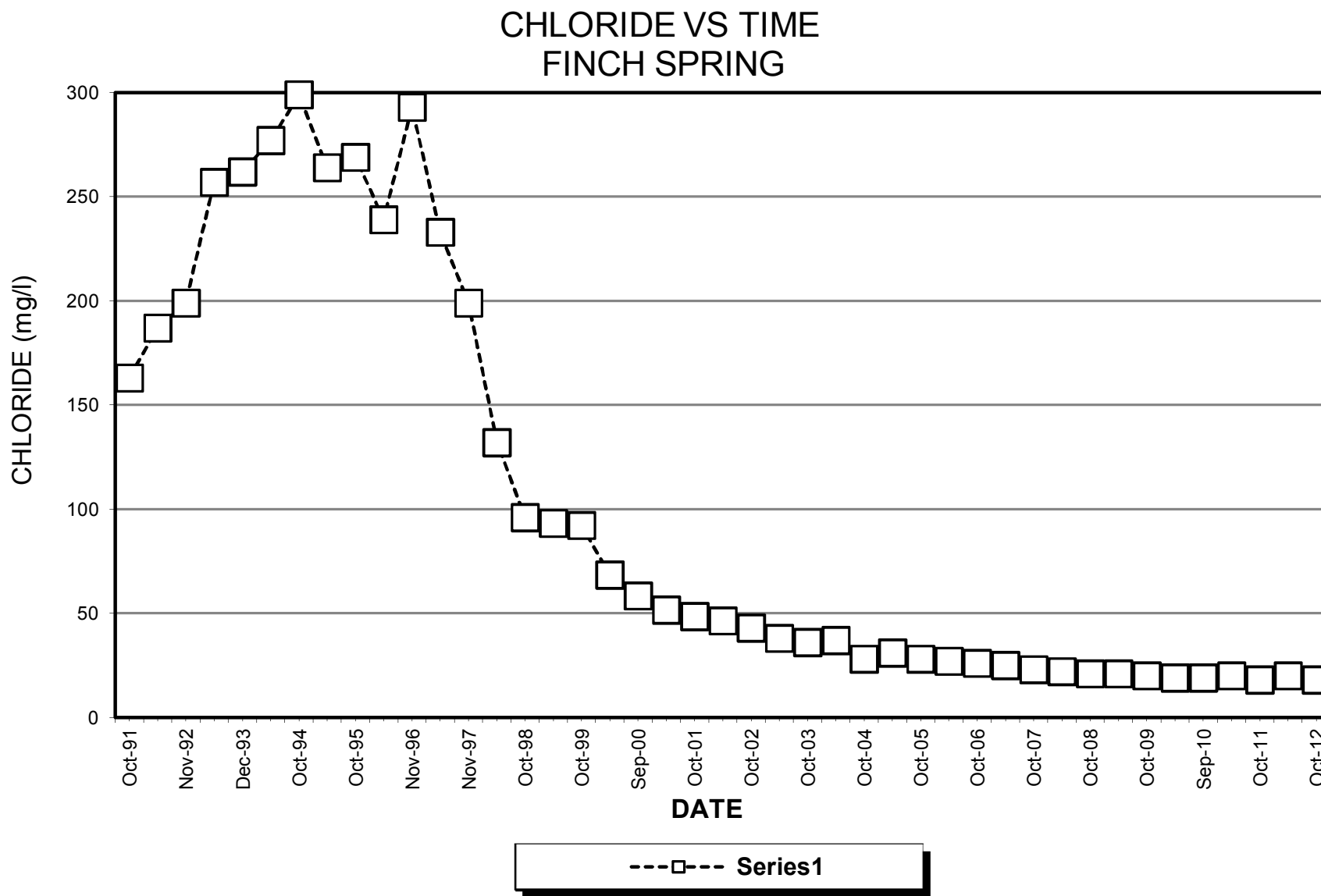
Values less than detection plotted at the detection limit

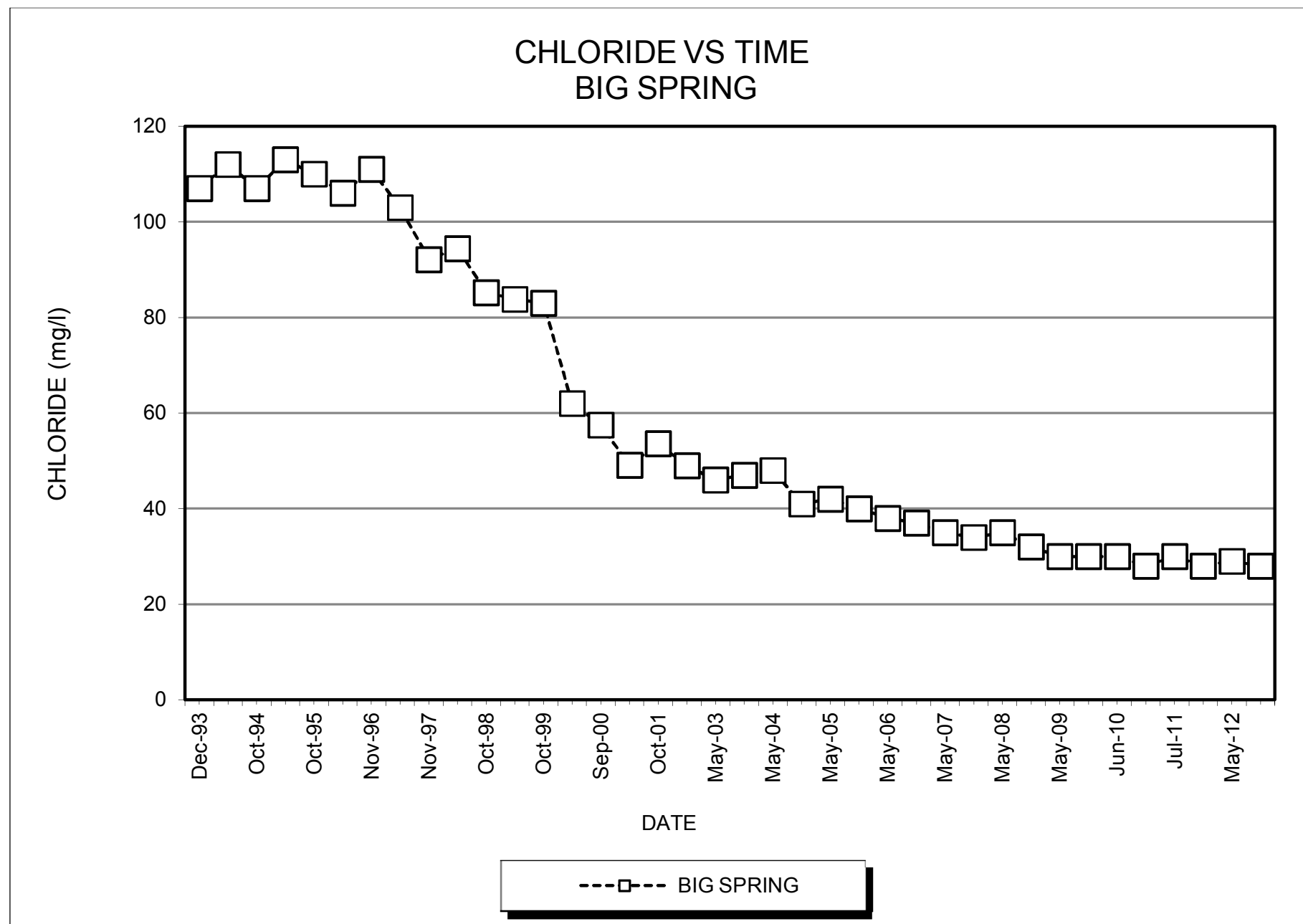


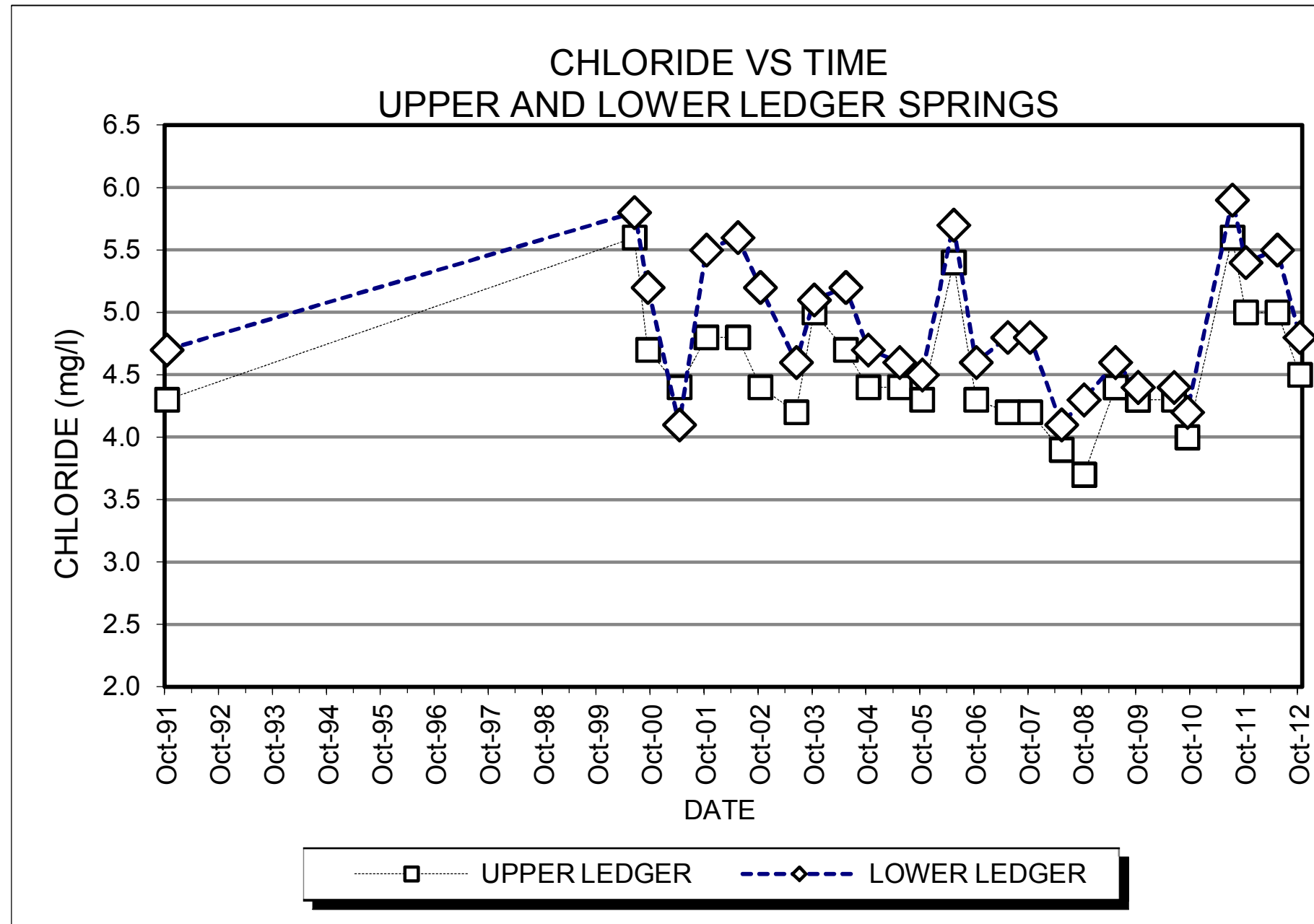


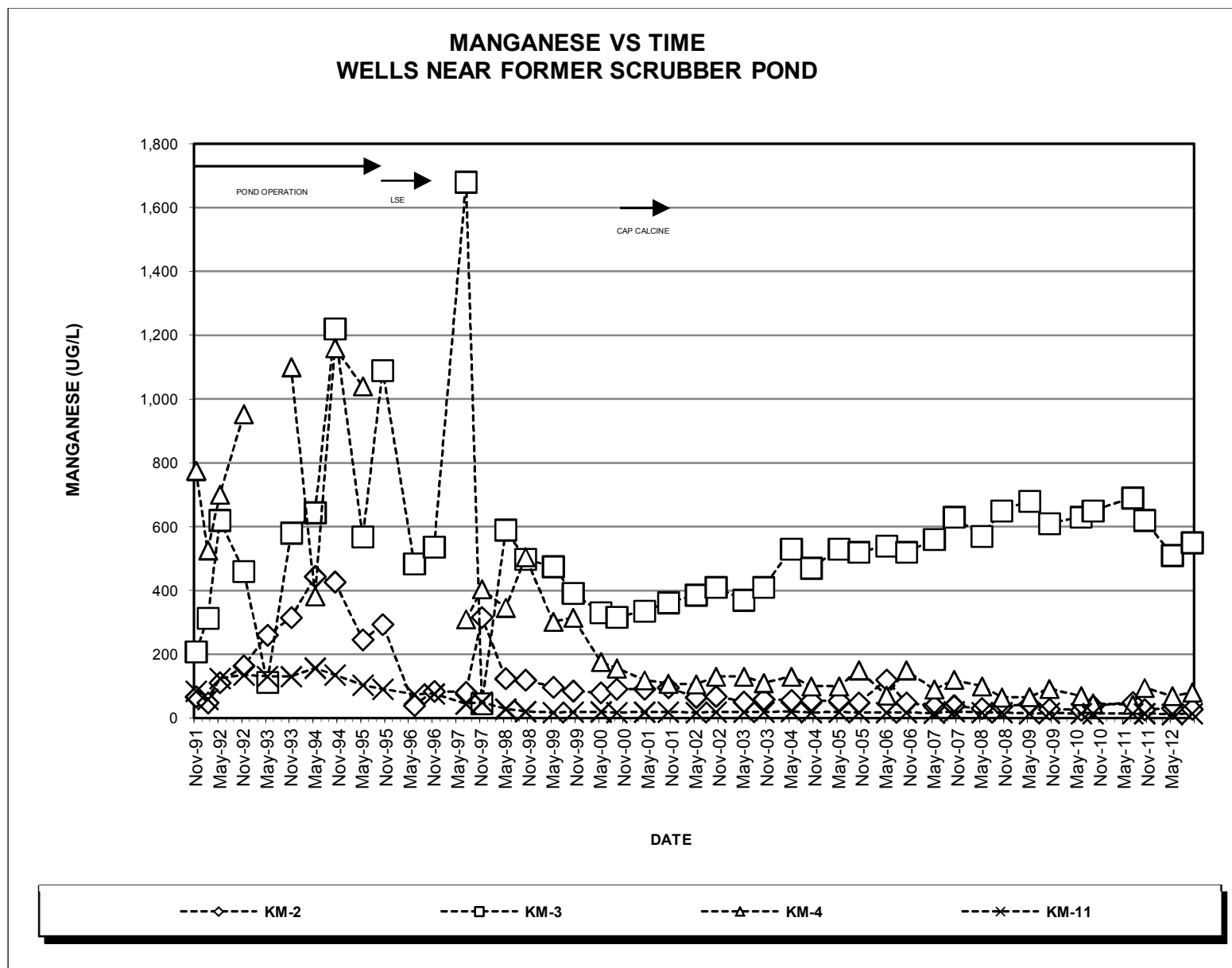








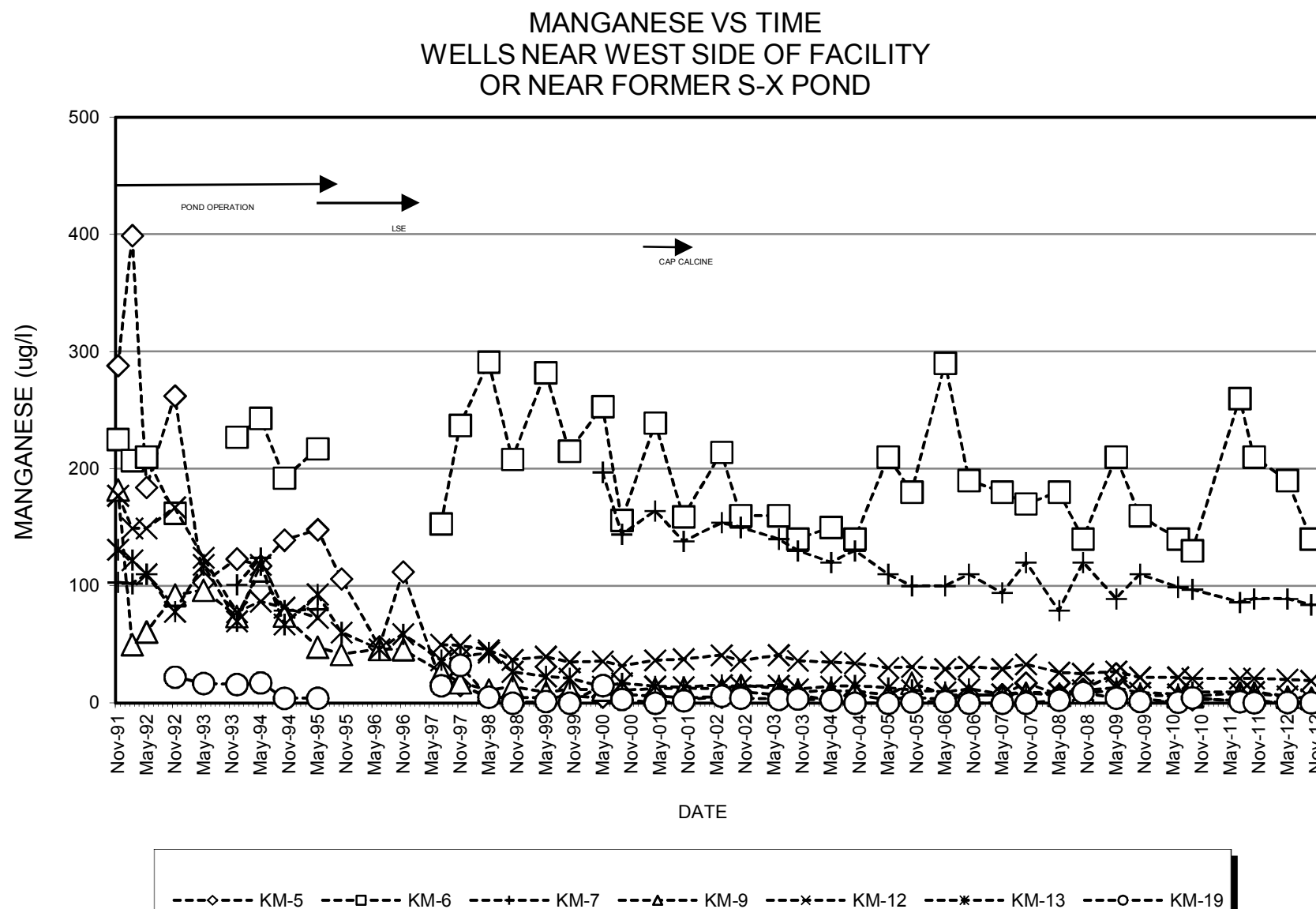




RBC FOR MANGANESE IS 180 ug/l

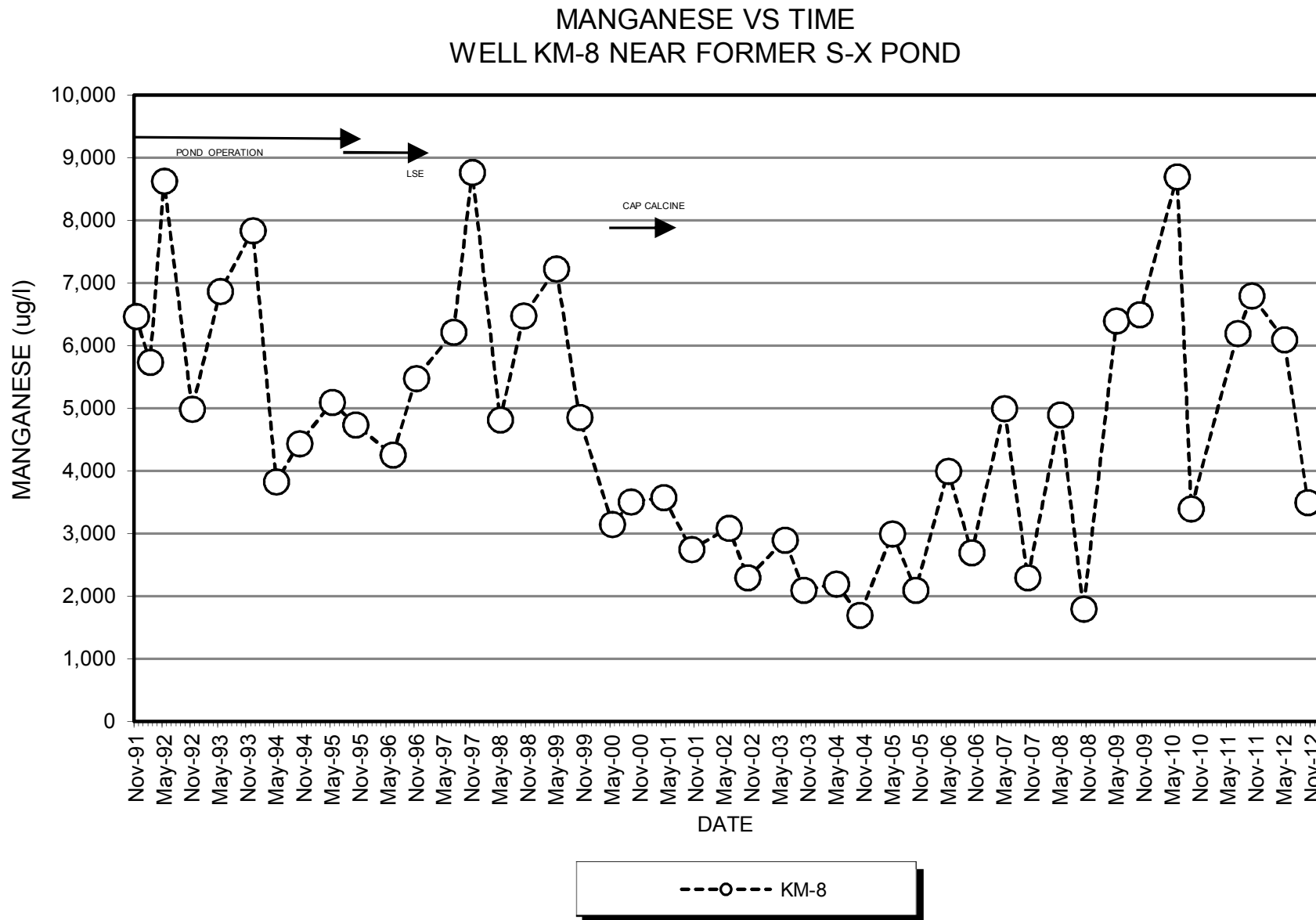
KM-2, KM-3, KM-11 ARE POC WELLS

VALUES LESS THAN DETECTION ARE PLOTTED AT DETECTION LIMIT

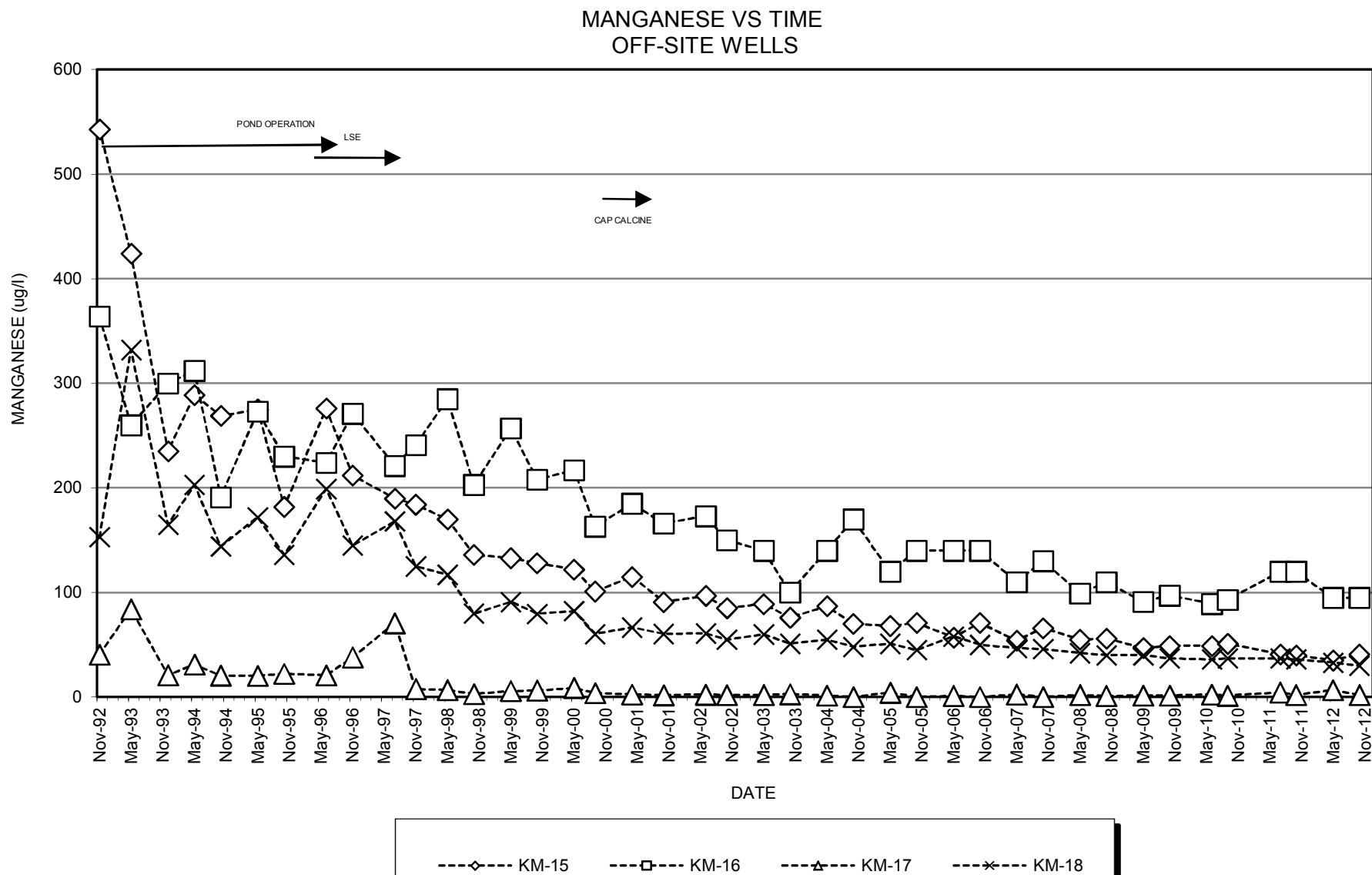


RBC FOR MANGANESE IS 180 ug/l

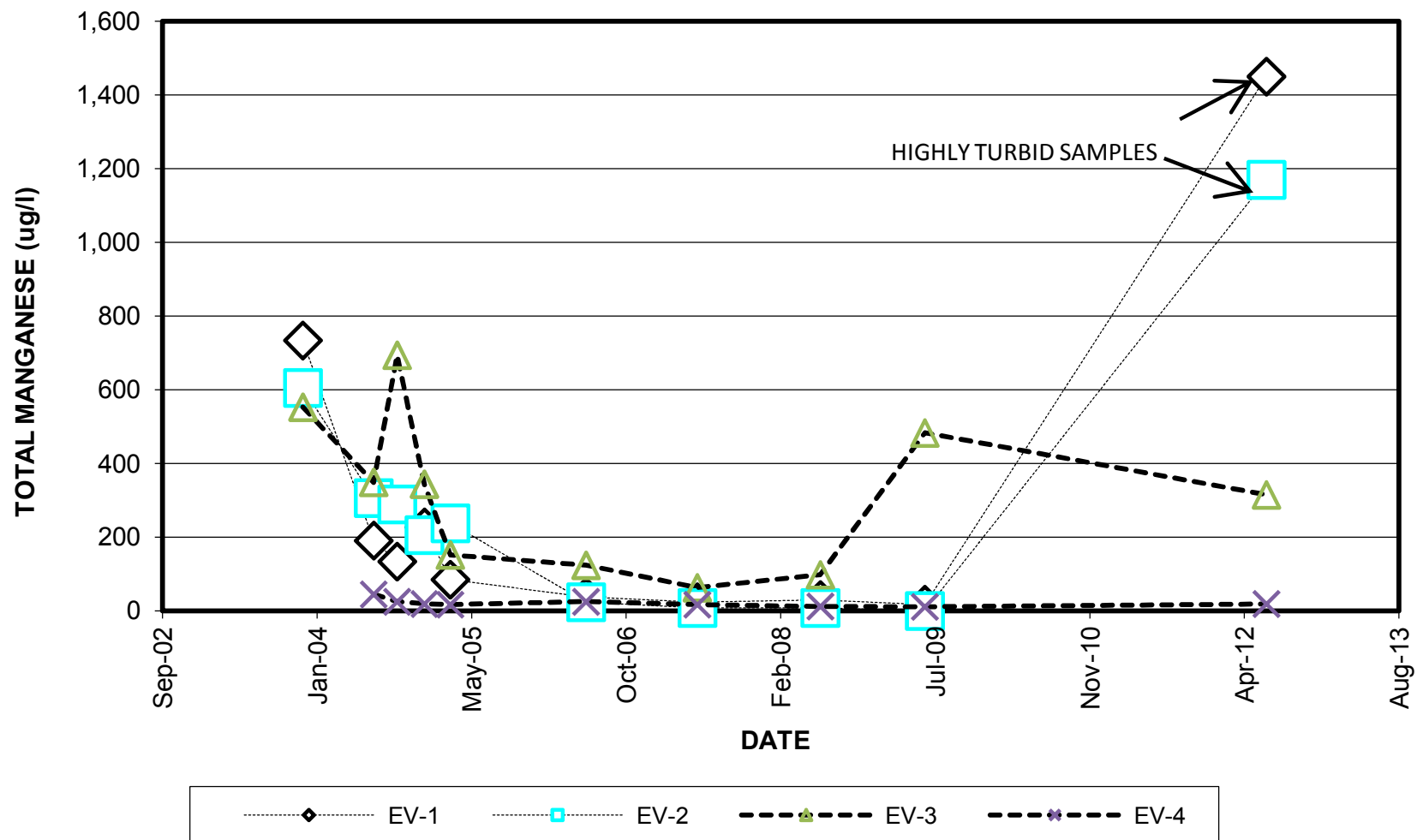
KM-5, KM-9, KM-12, KM-13, KM-19 ARE POC WELLS

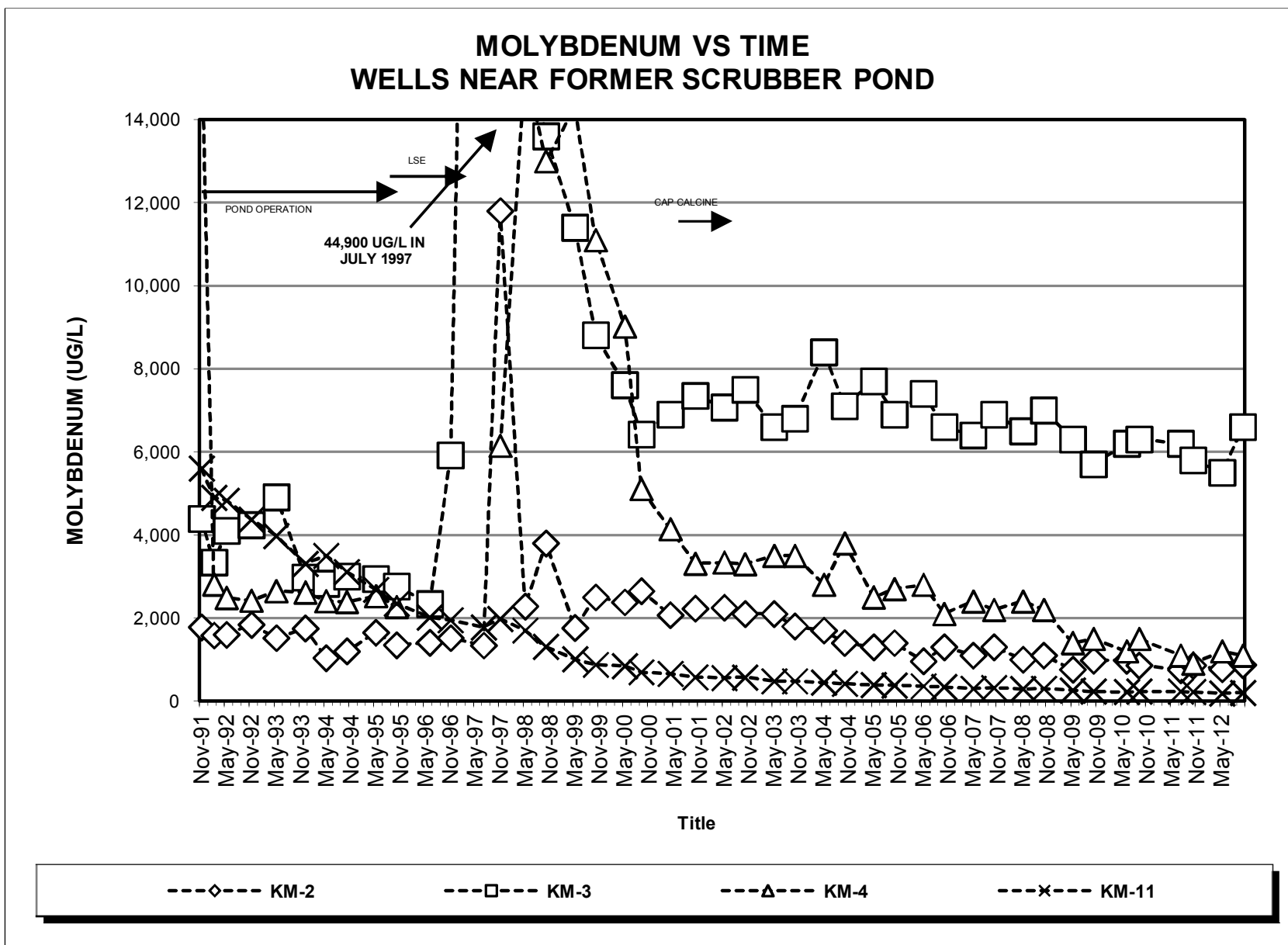


RBC FOR MANGANESE IS 180 ug/l
KM-8 IS A POC WELL

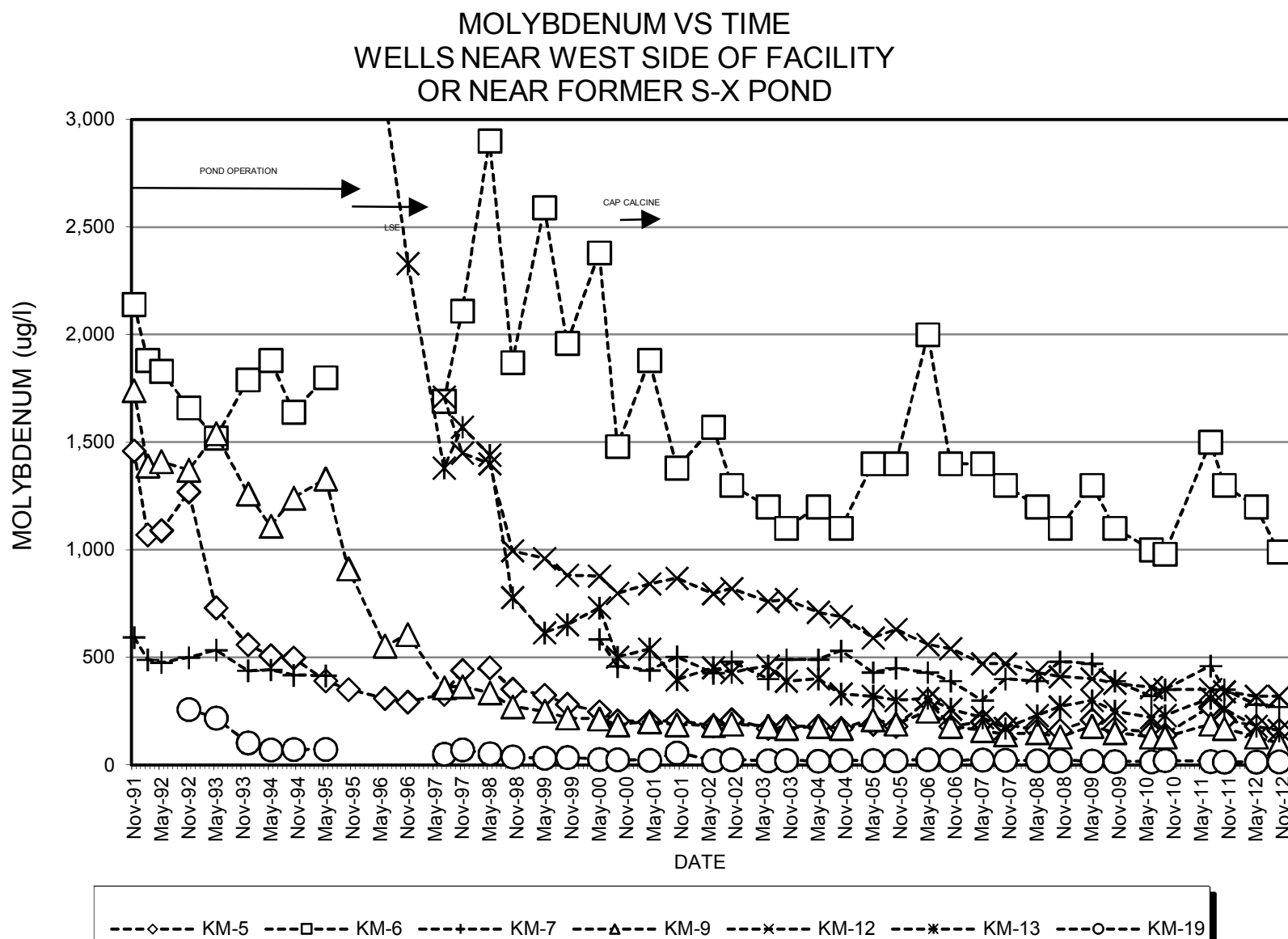


MANGANESE VS TIME - EVERGREEN WELLS



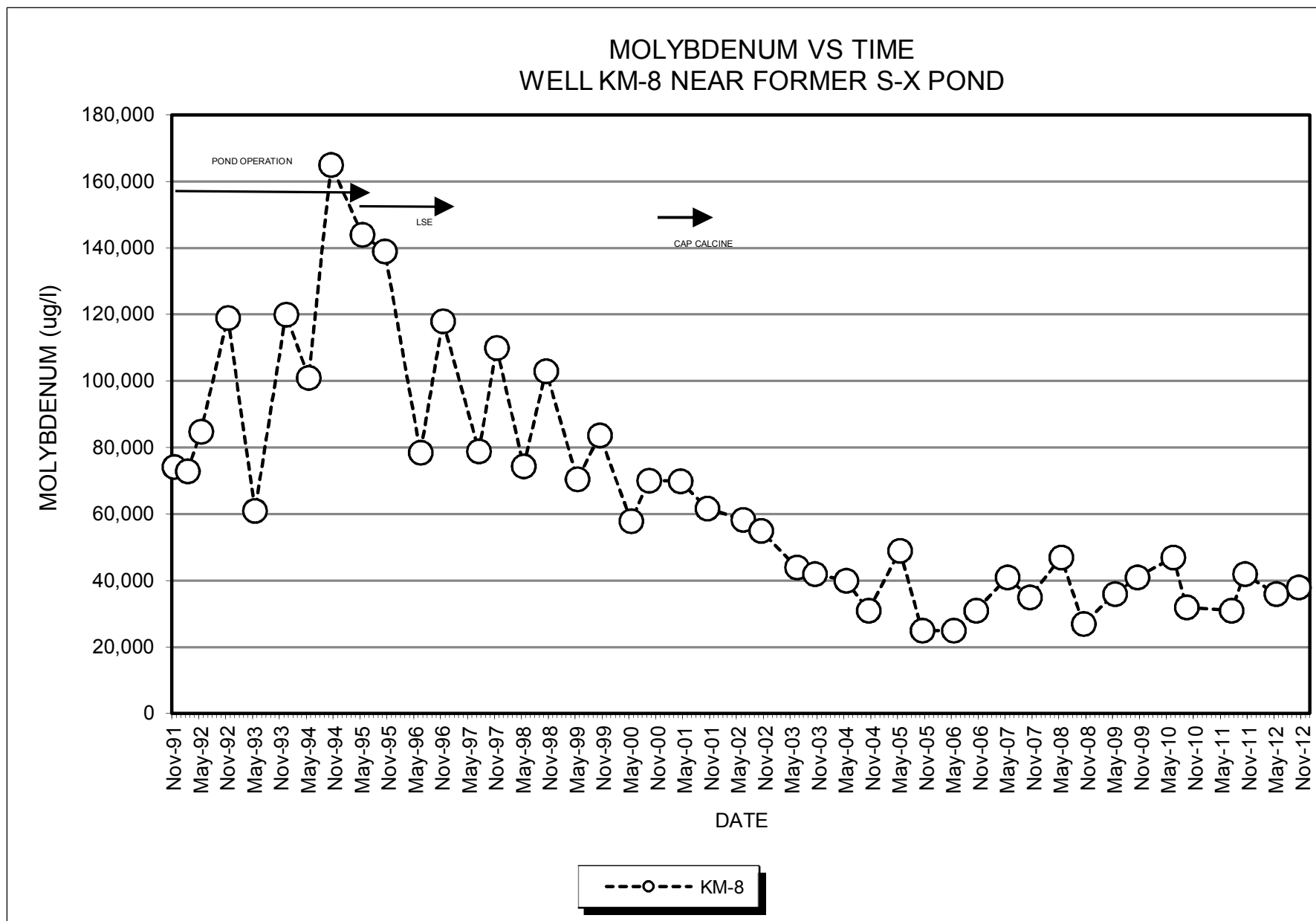


RBC FOR Molybdenum IS 180 ug/l
KM-2, KM-3, KM-11 ARE POC WELLS

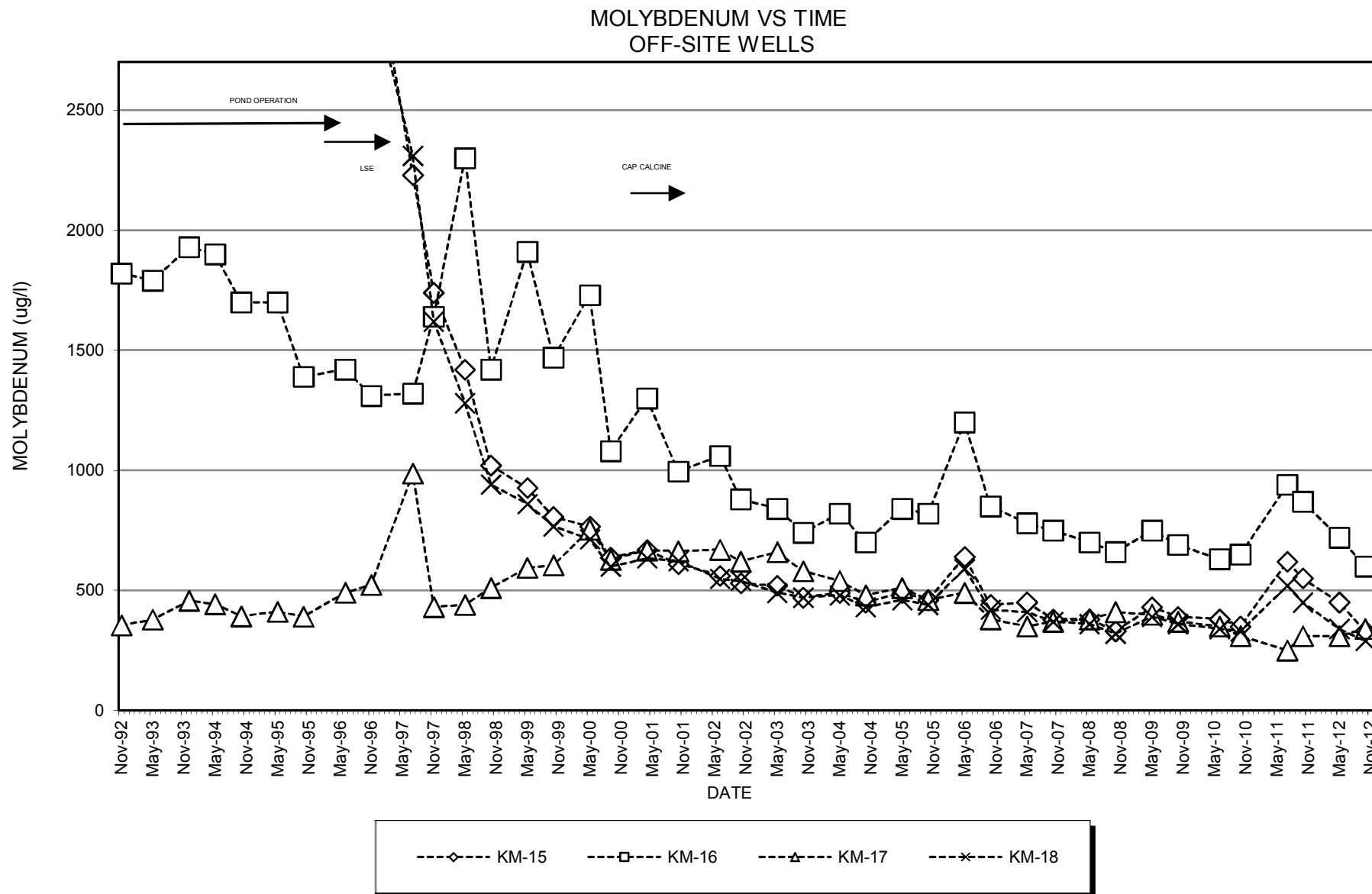


RBC FOR MOLYBDENUM IS 180 ug/l

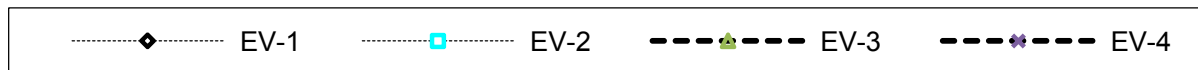
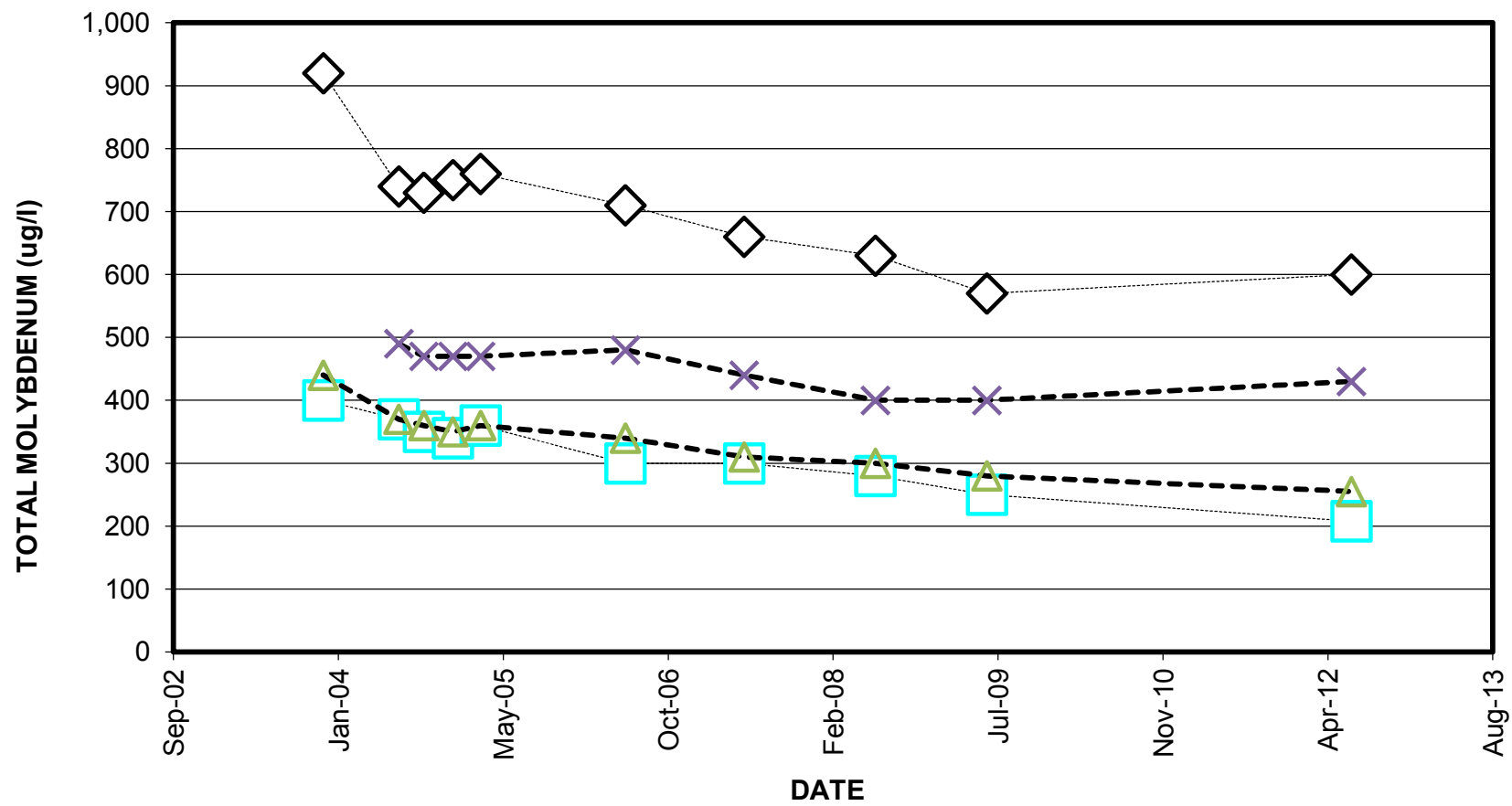
KM-5, KM-9, KM-12, KM-13, KM-19 ARE POC WELLS

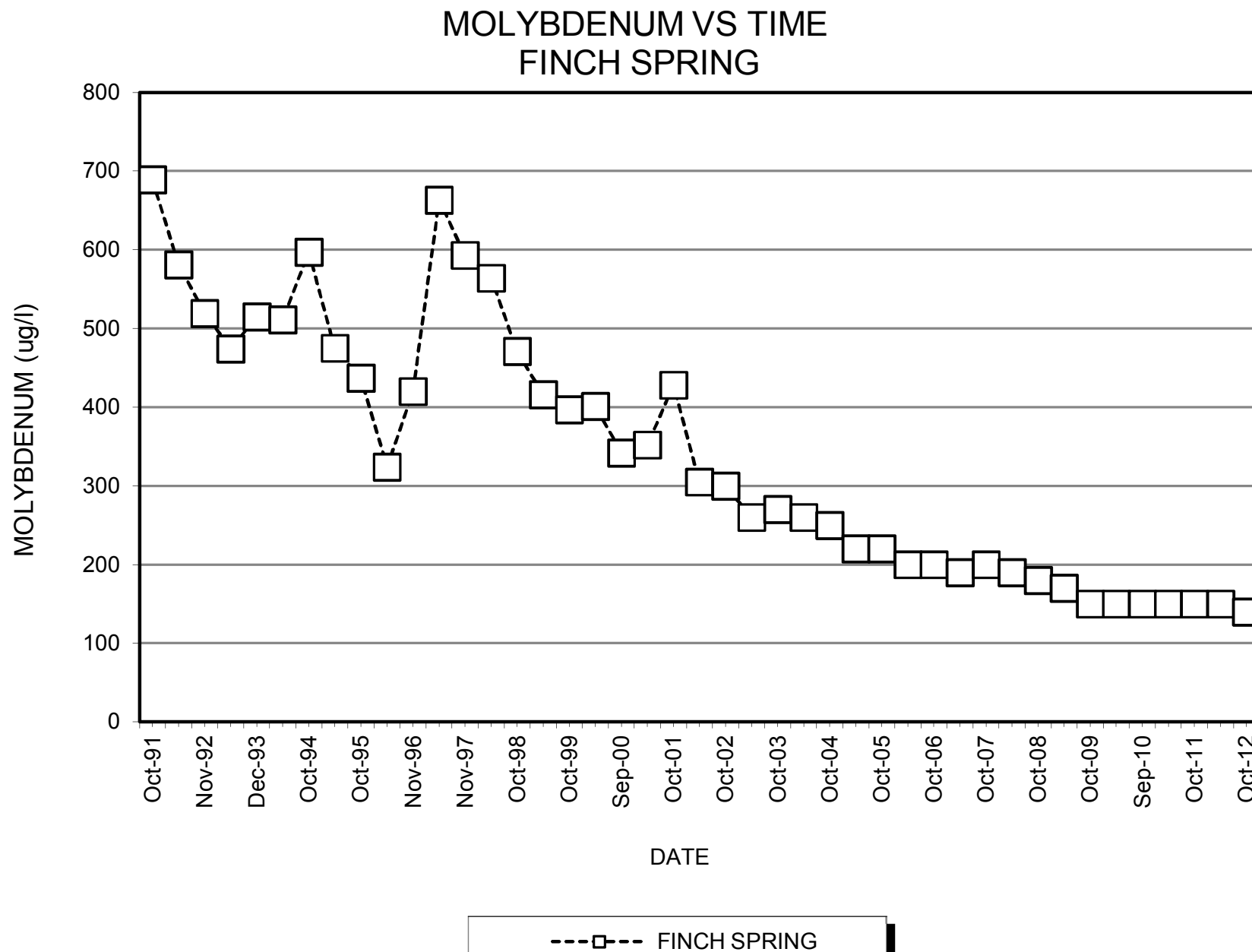


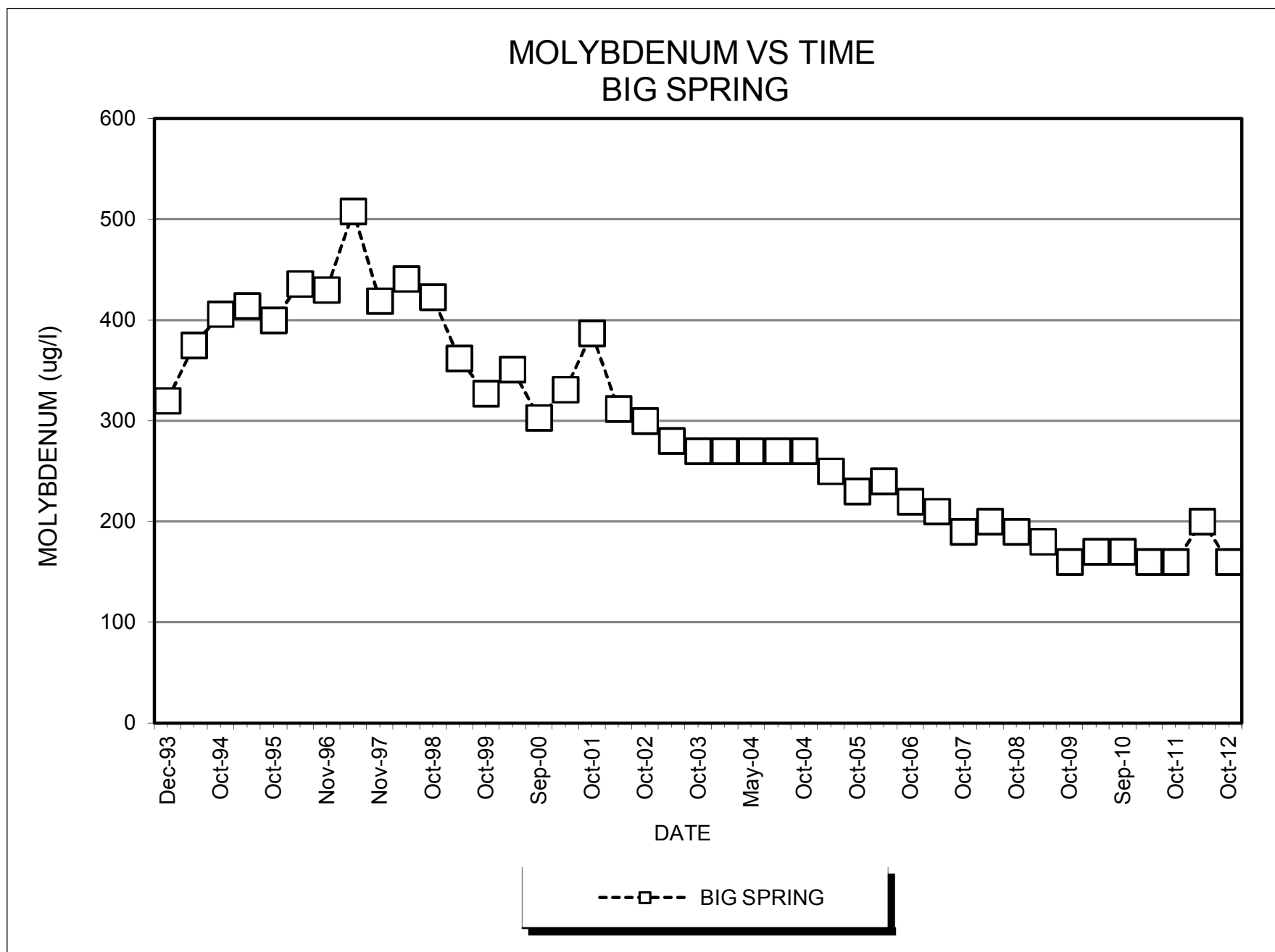
RBC FOR MOLYBDENUM IS 180 ug/l
KM-8 IS A POC WELL

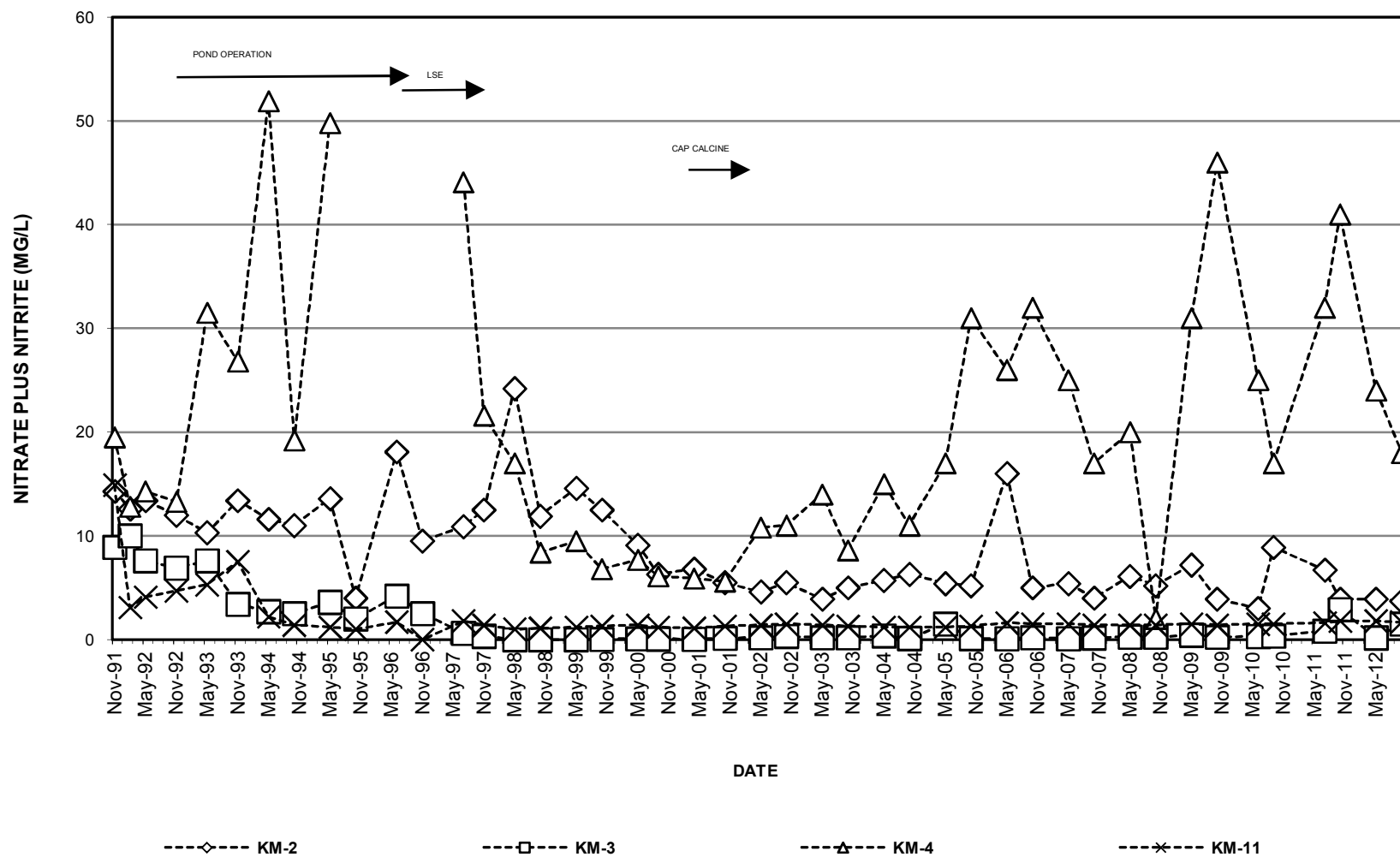


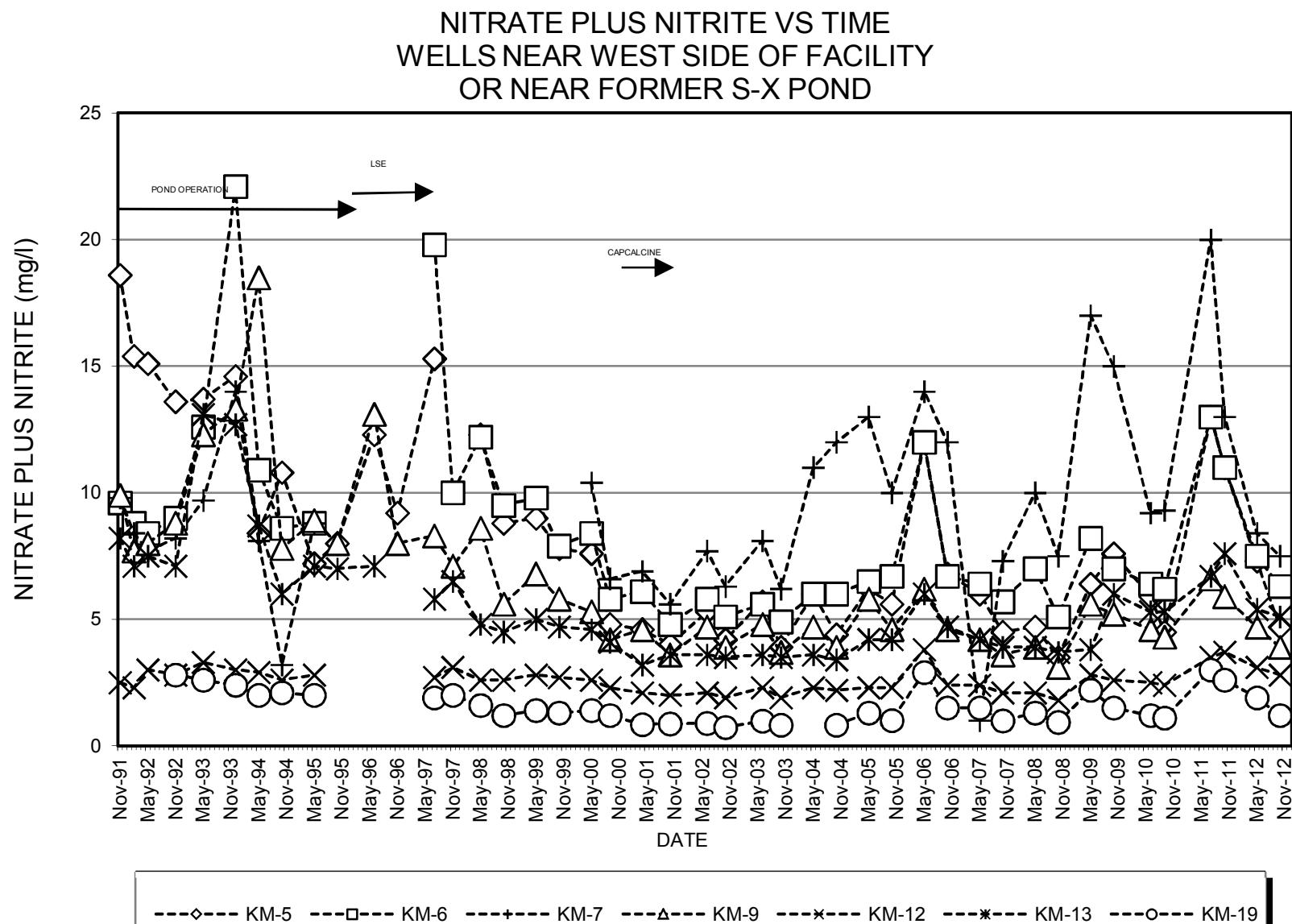
MOLYBDENUM VS TIME - EVERGREEN WELLS

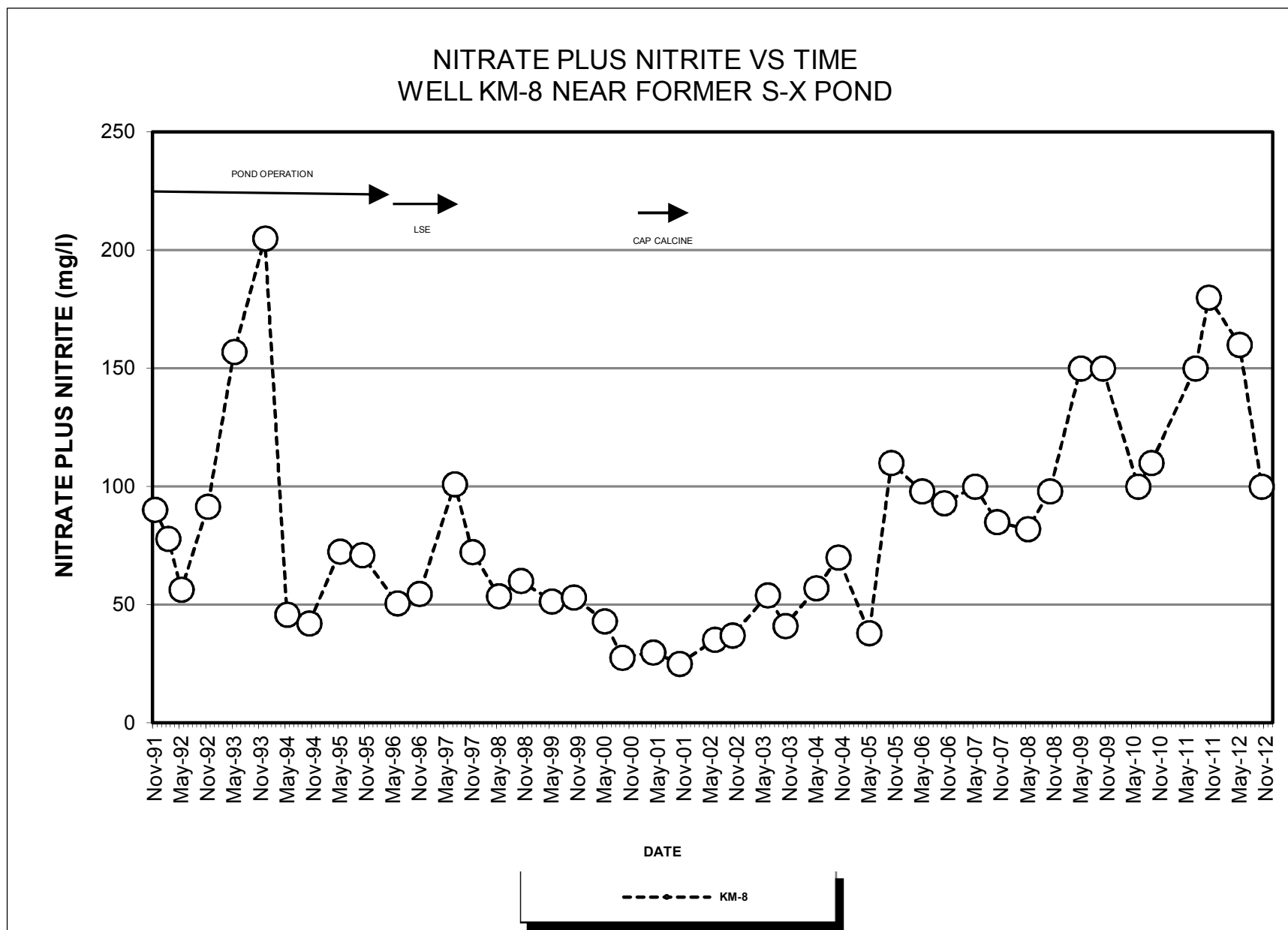


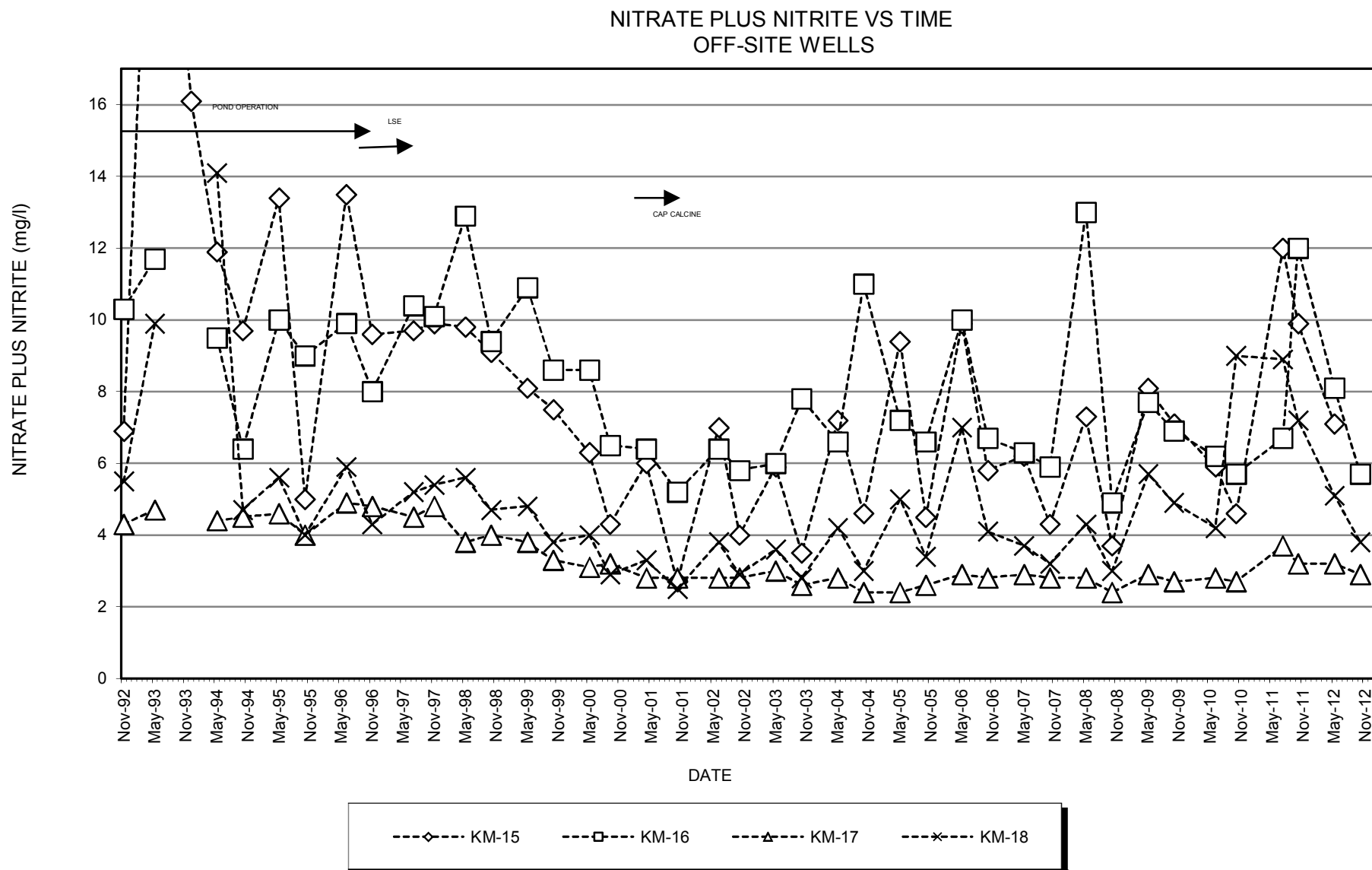


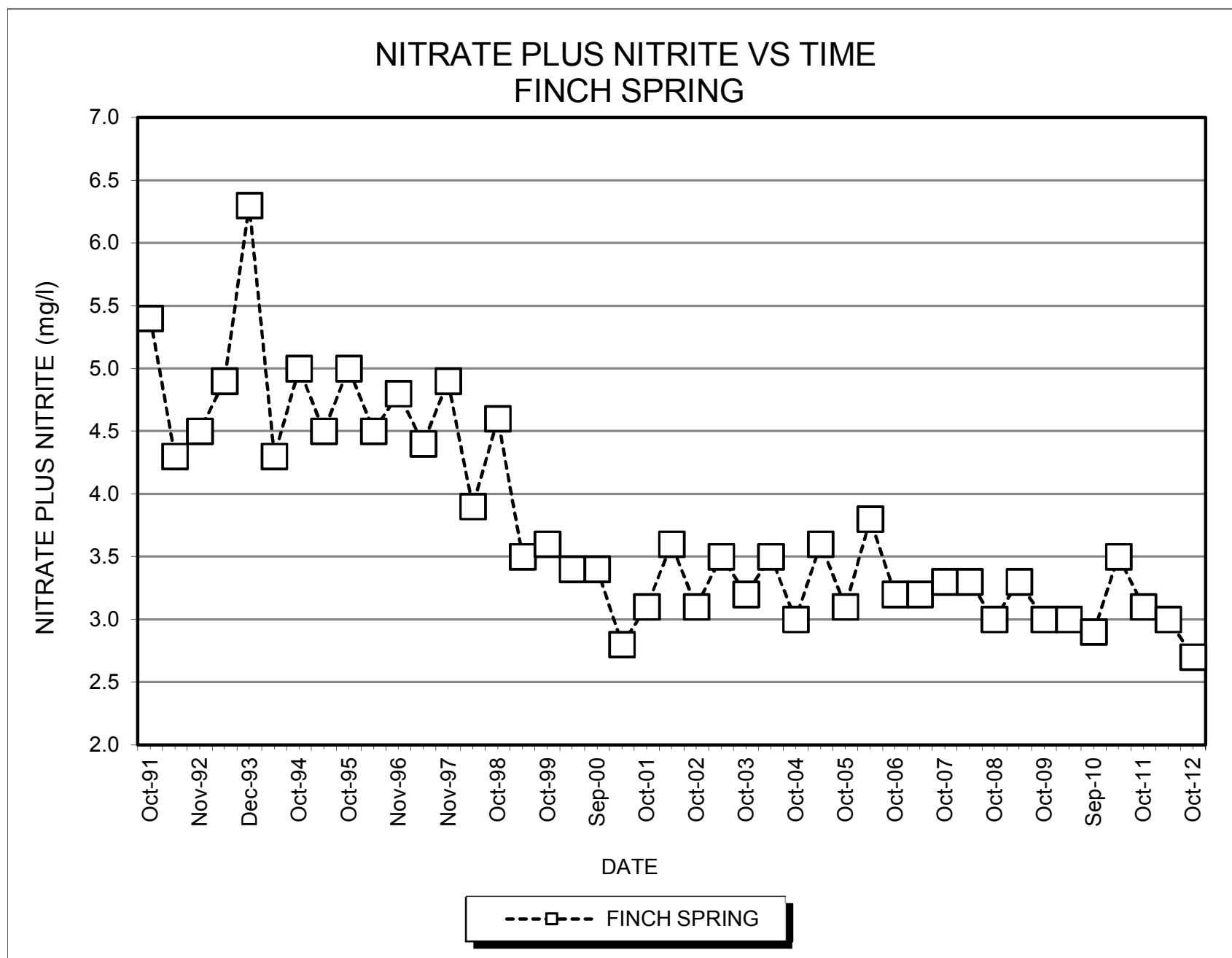


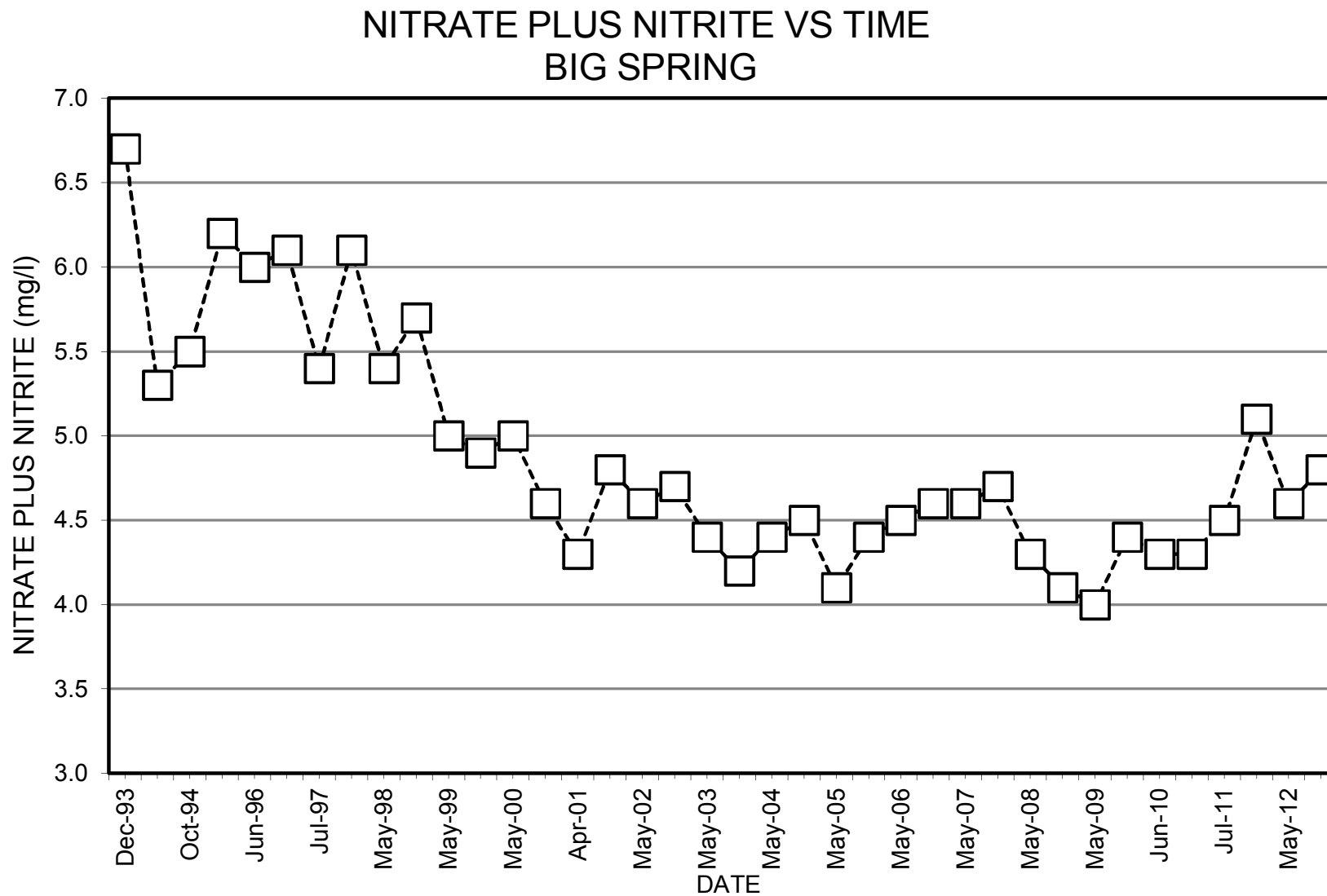
**NITRATE PLUS NITRITE VS TIME
WELLS NEAR FORMER SCRUBBER POND**



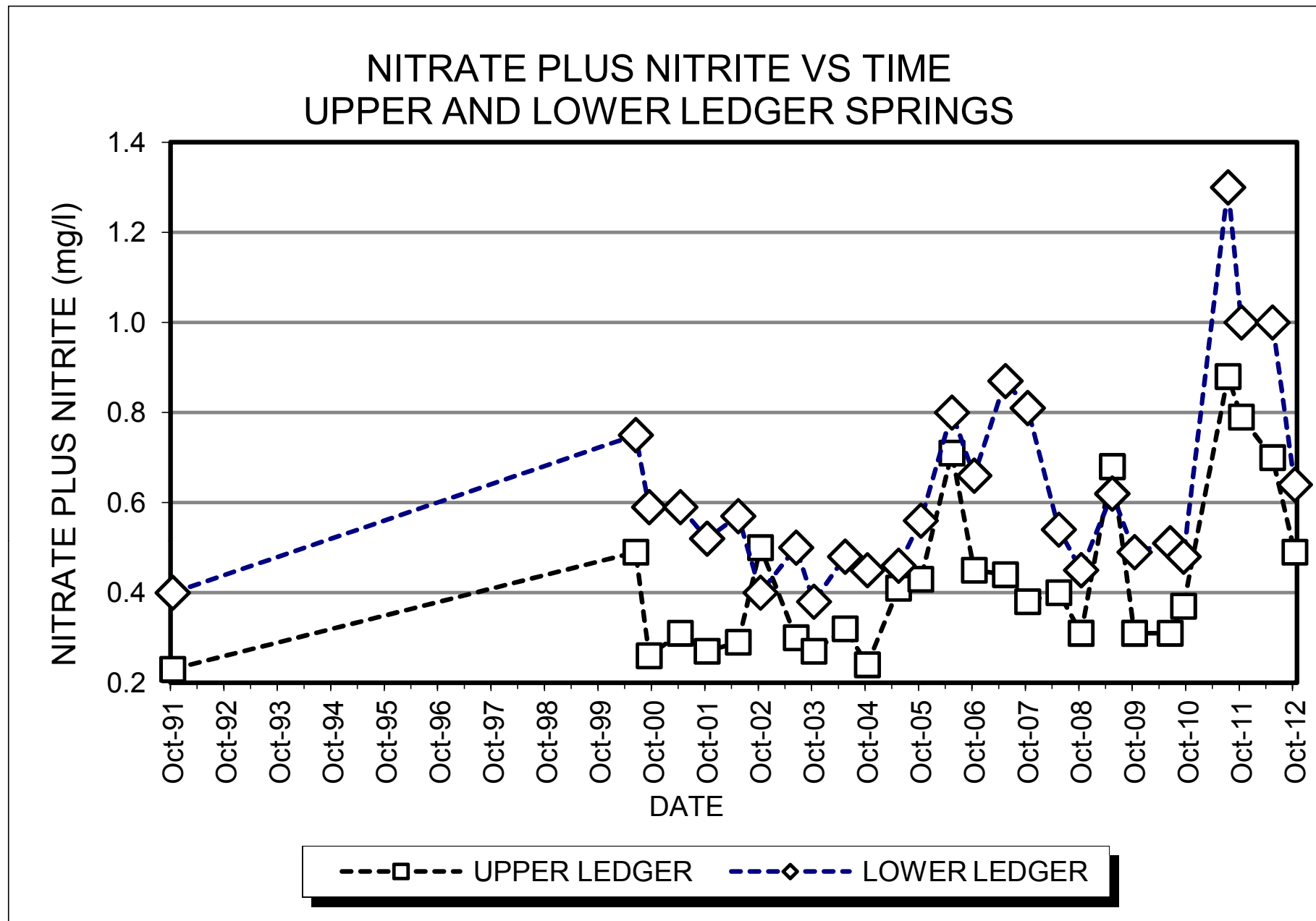


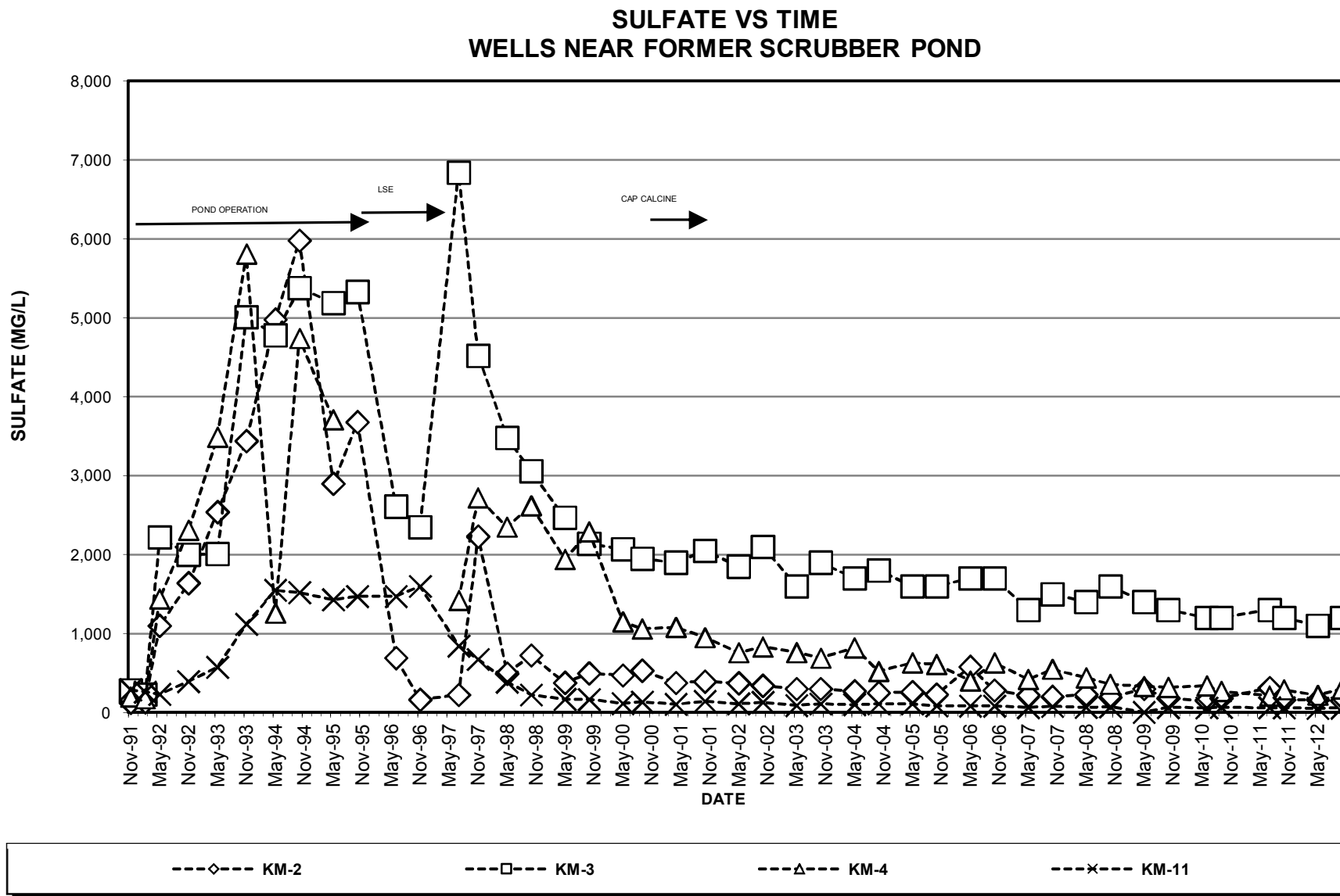


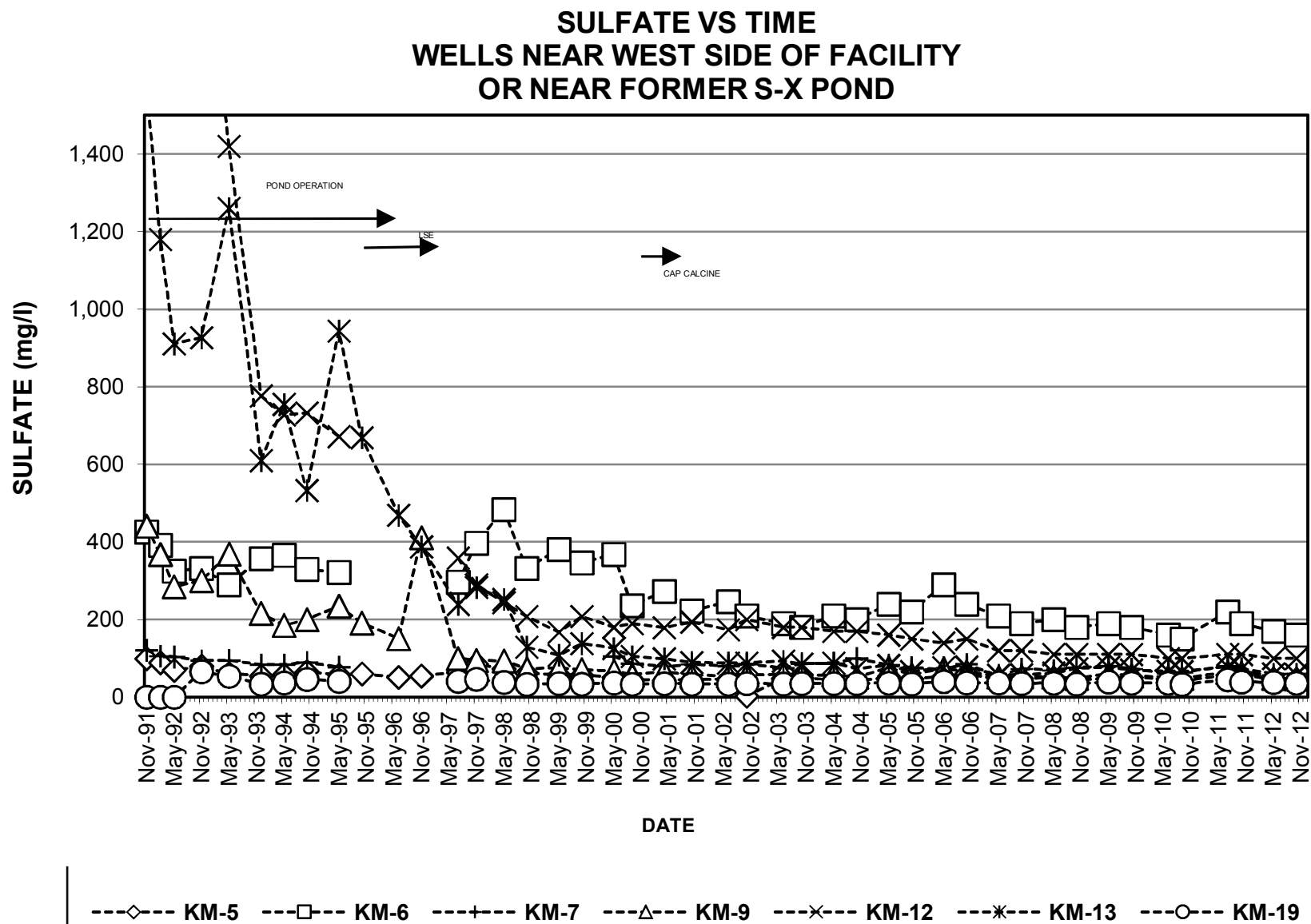


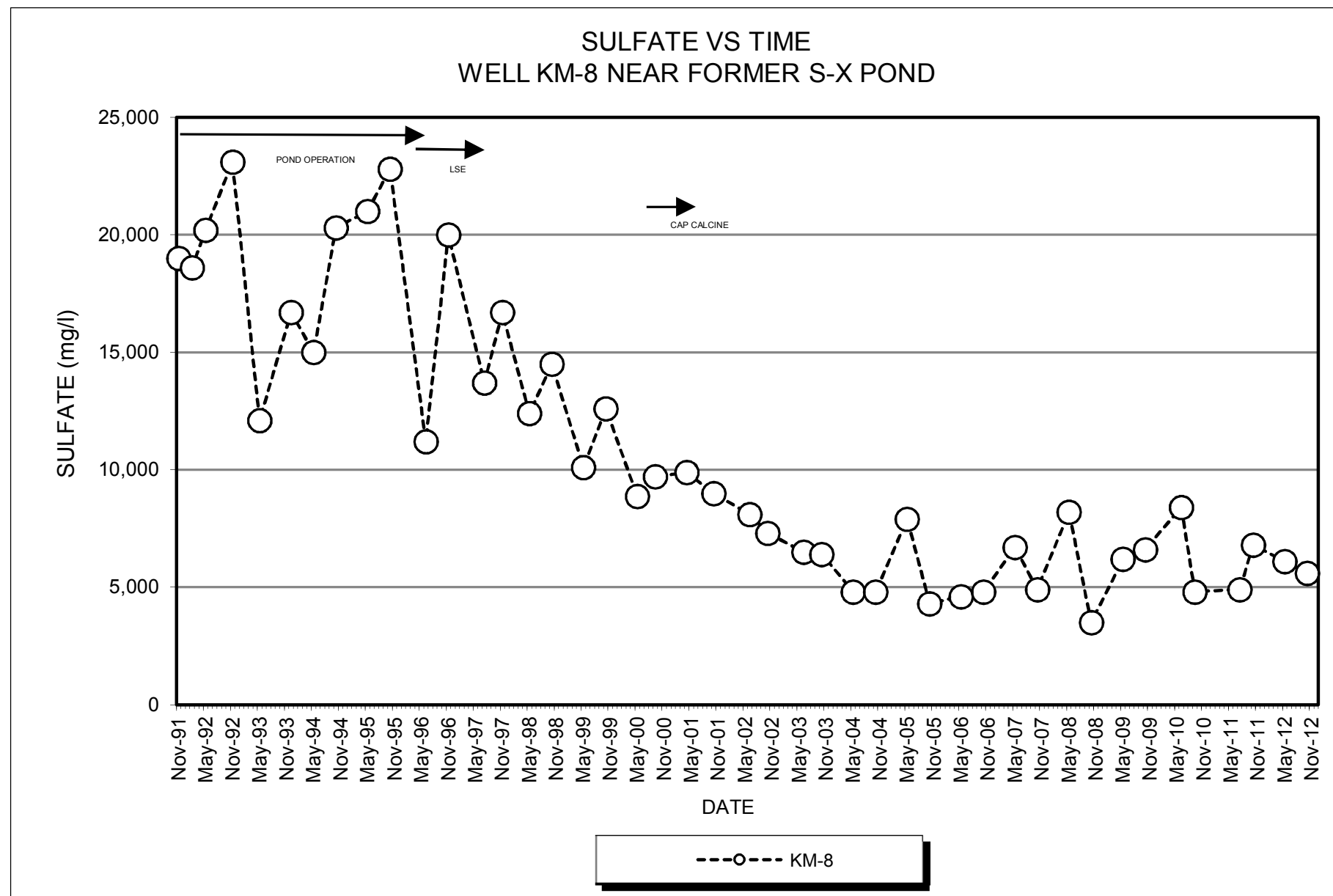


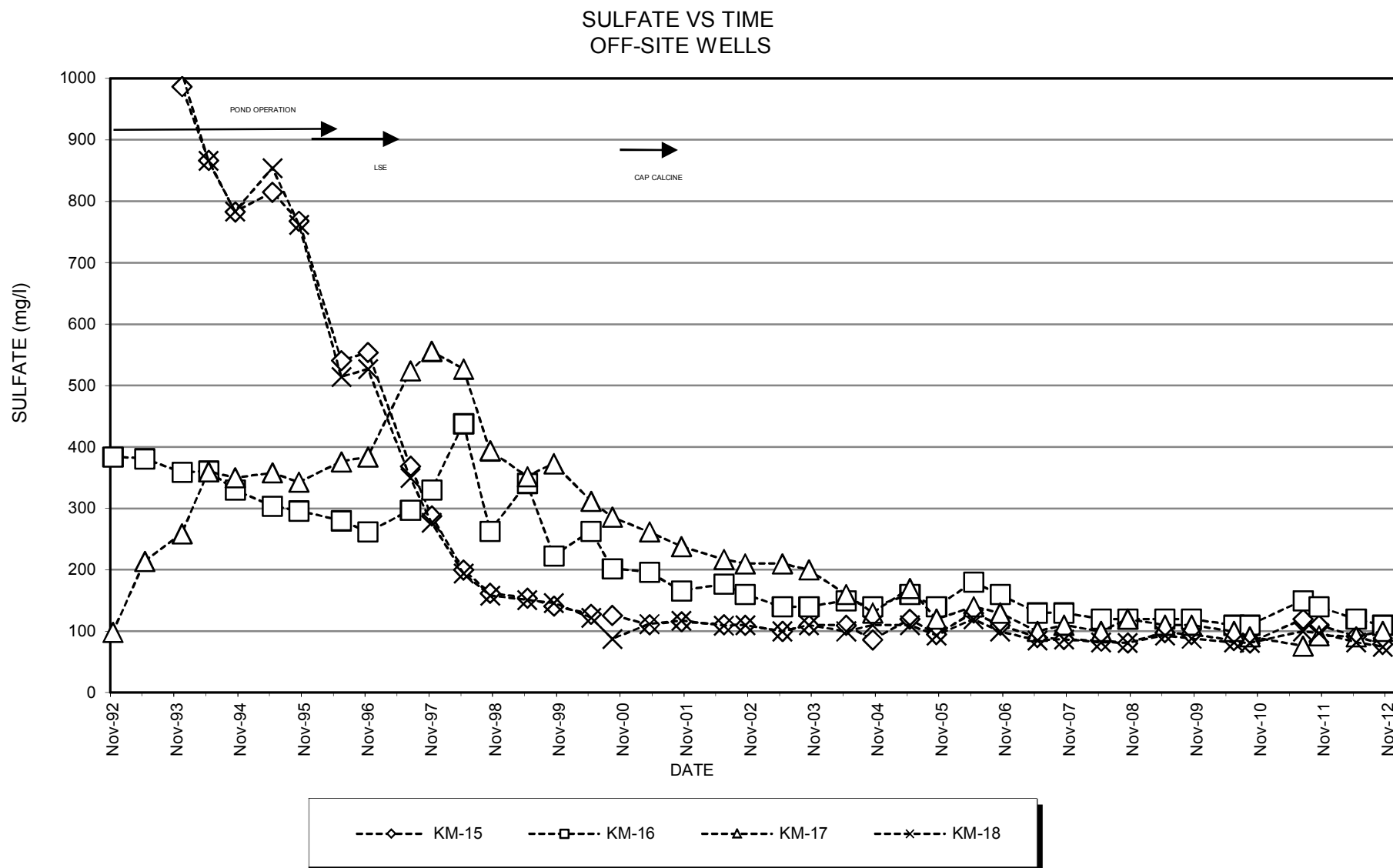
---□--- BIG SPRING

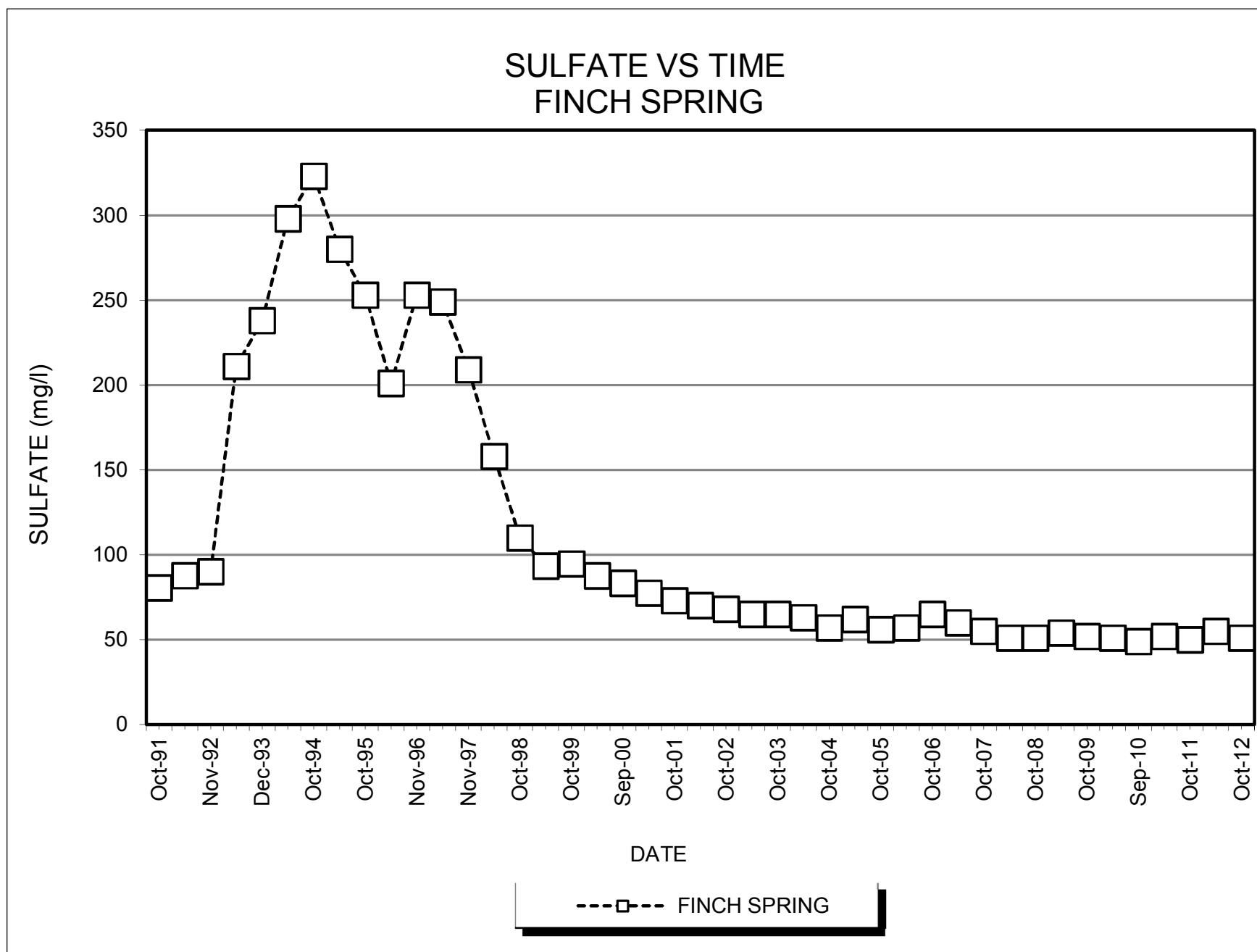


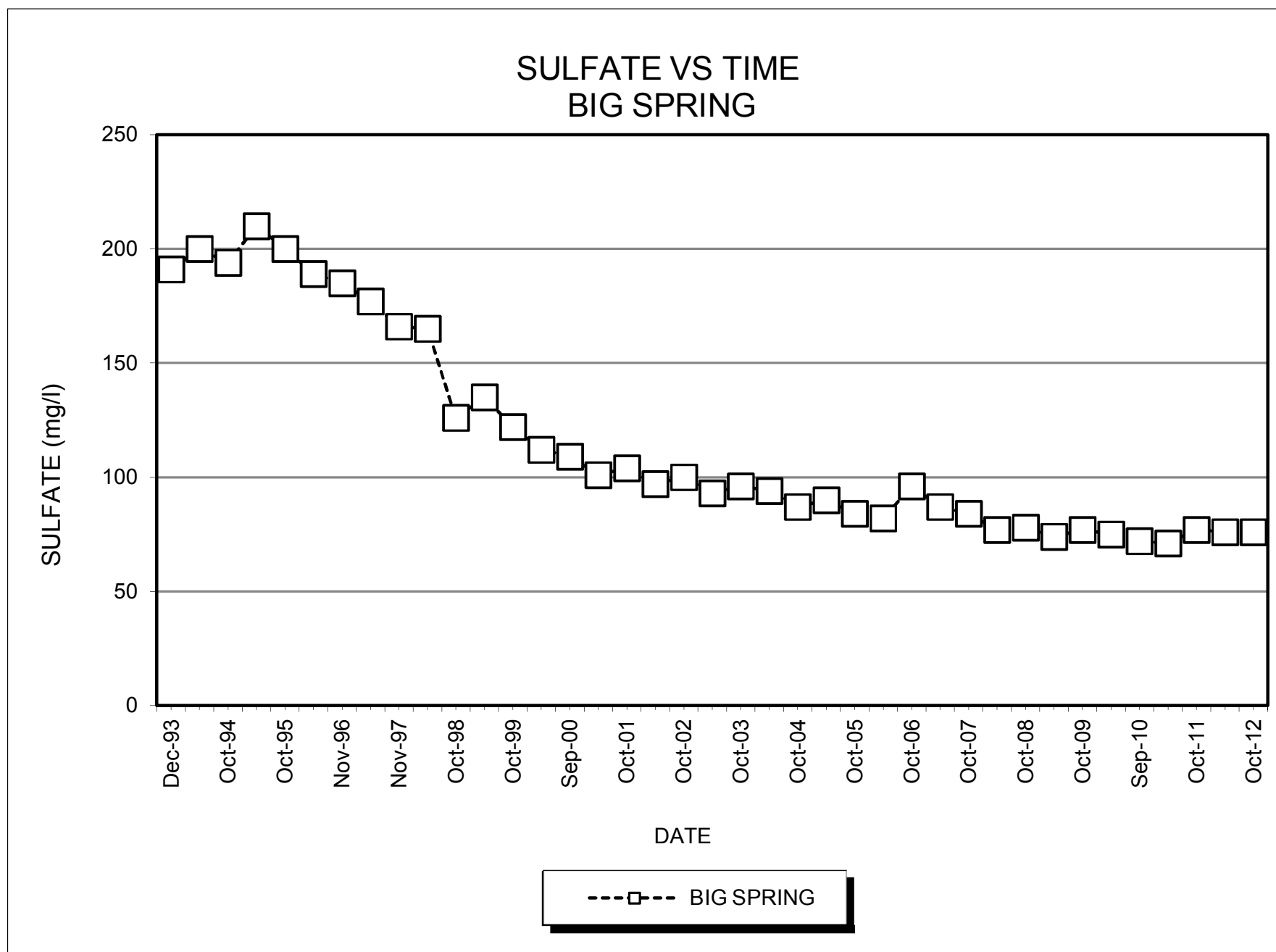


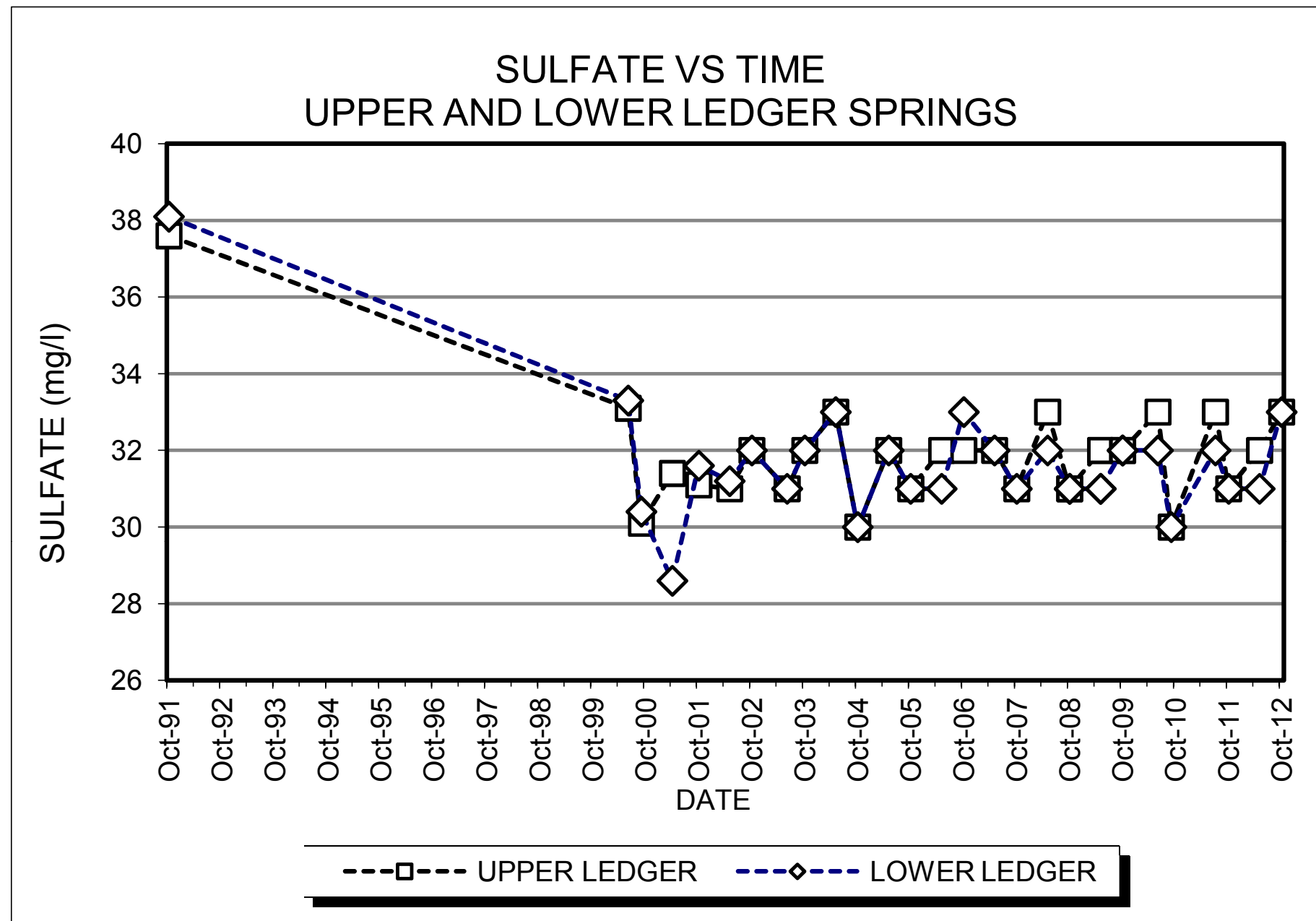


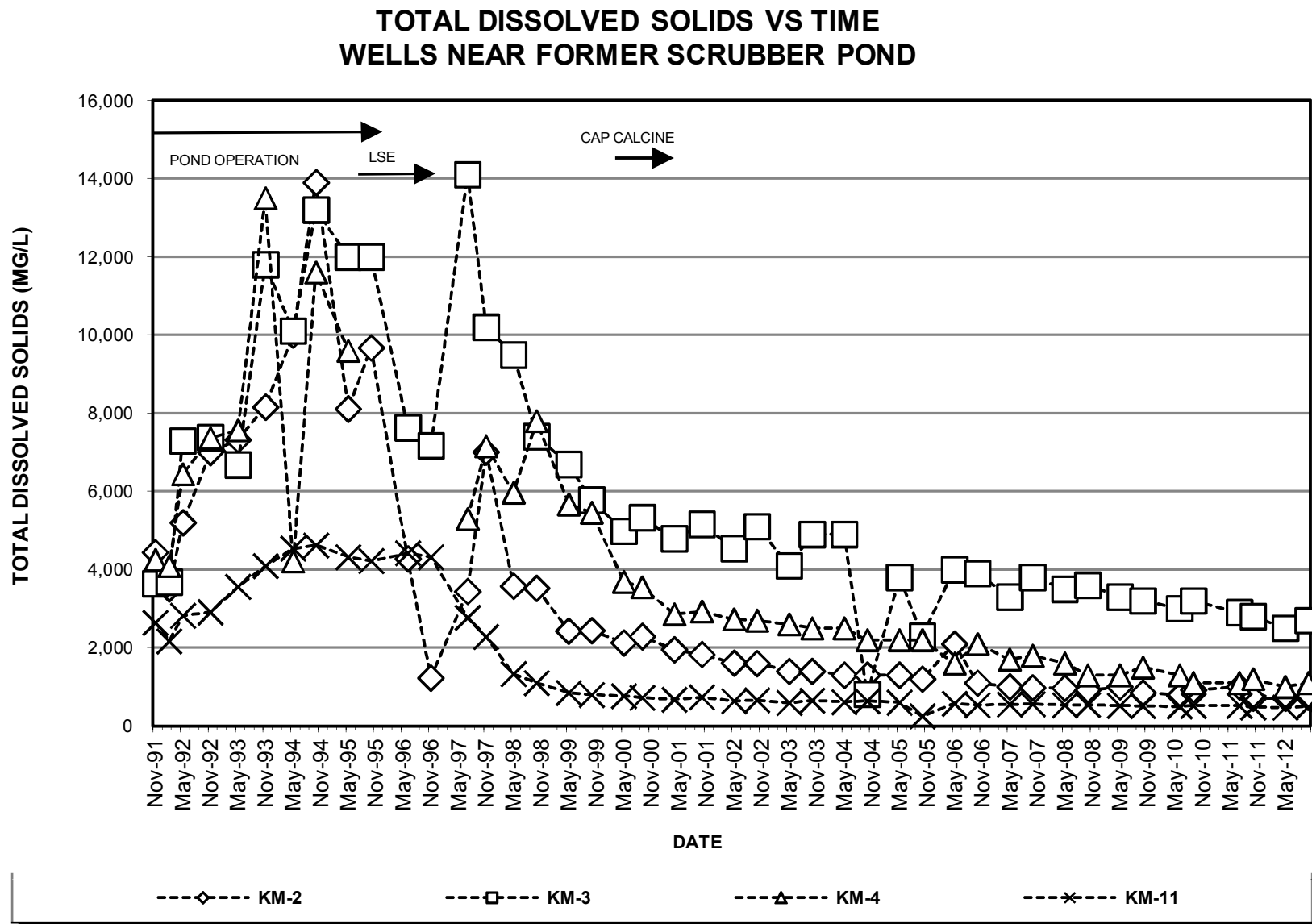


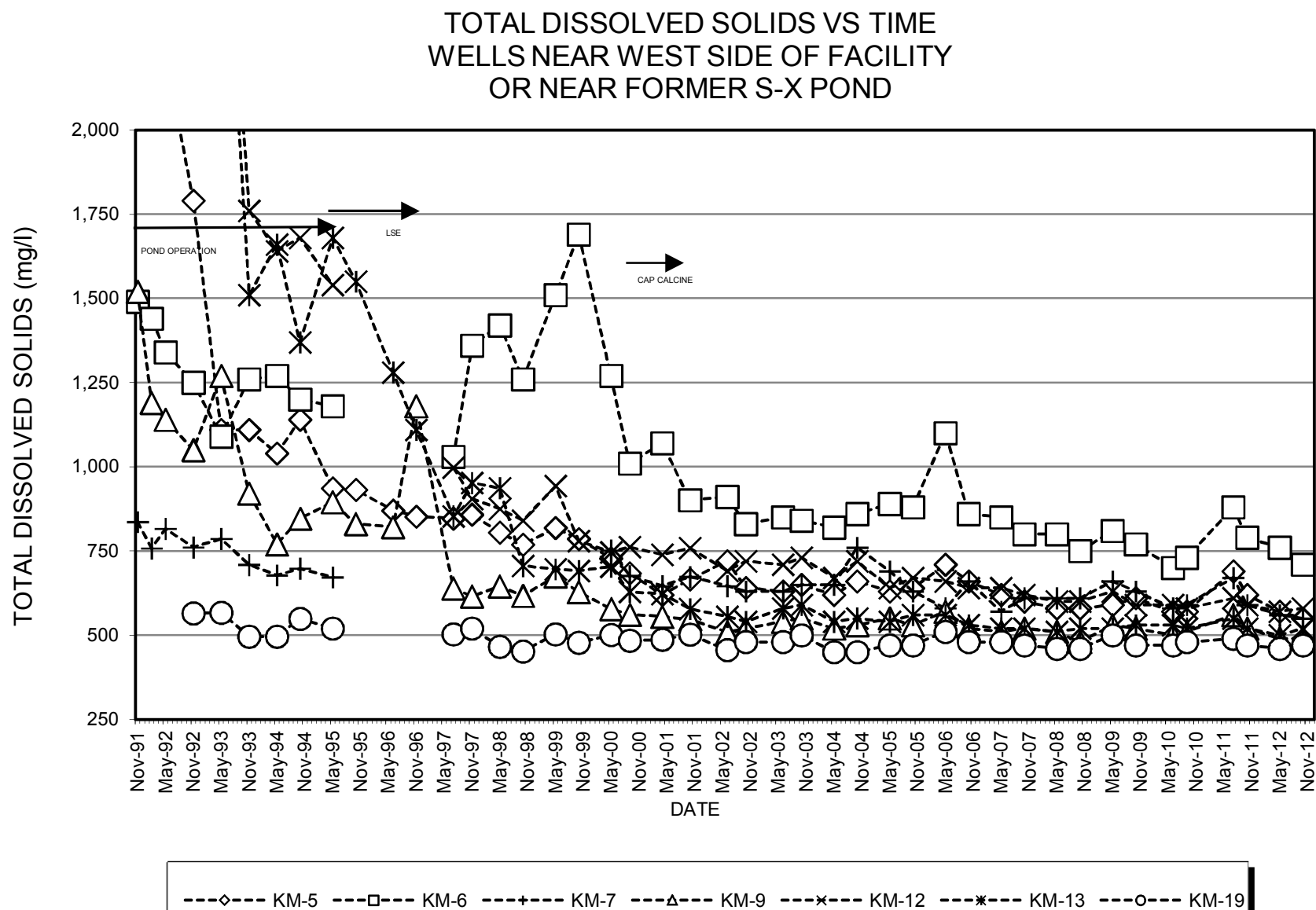


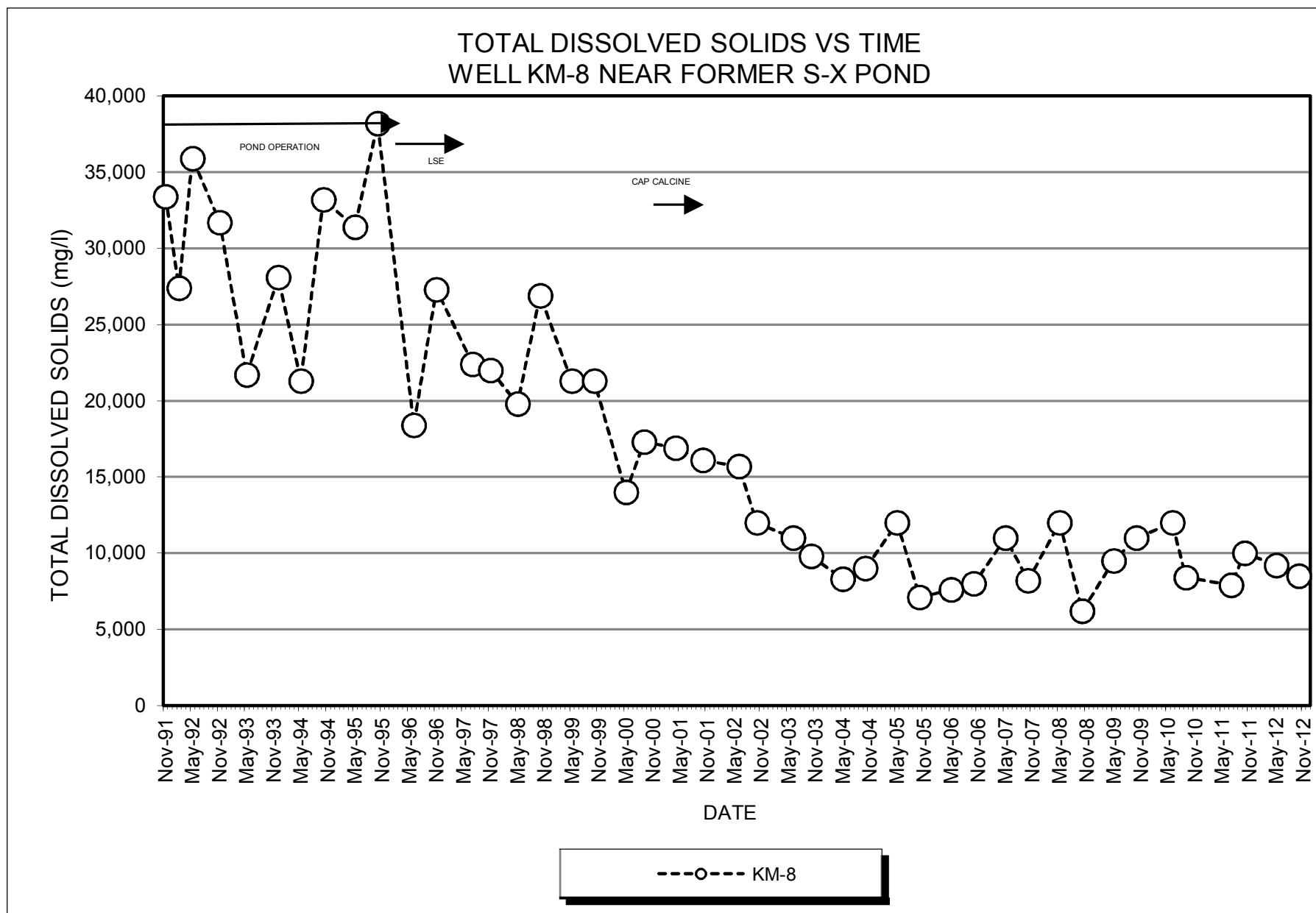


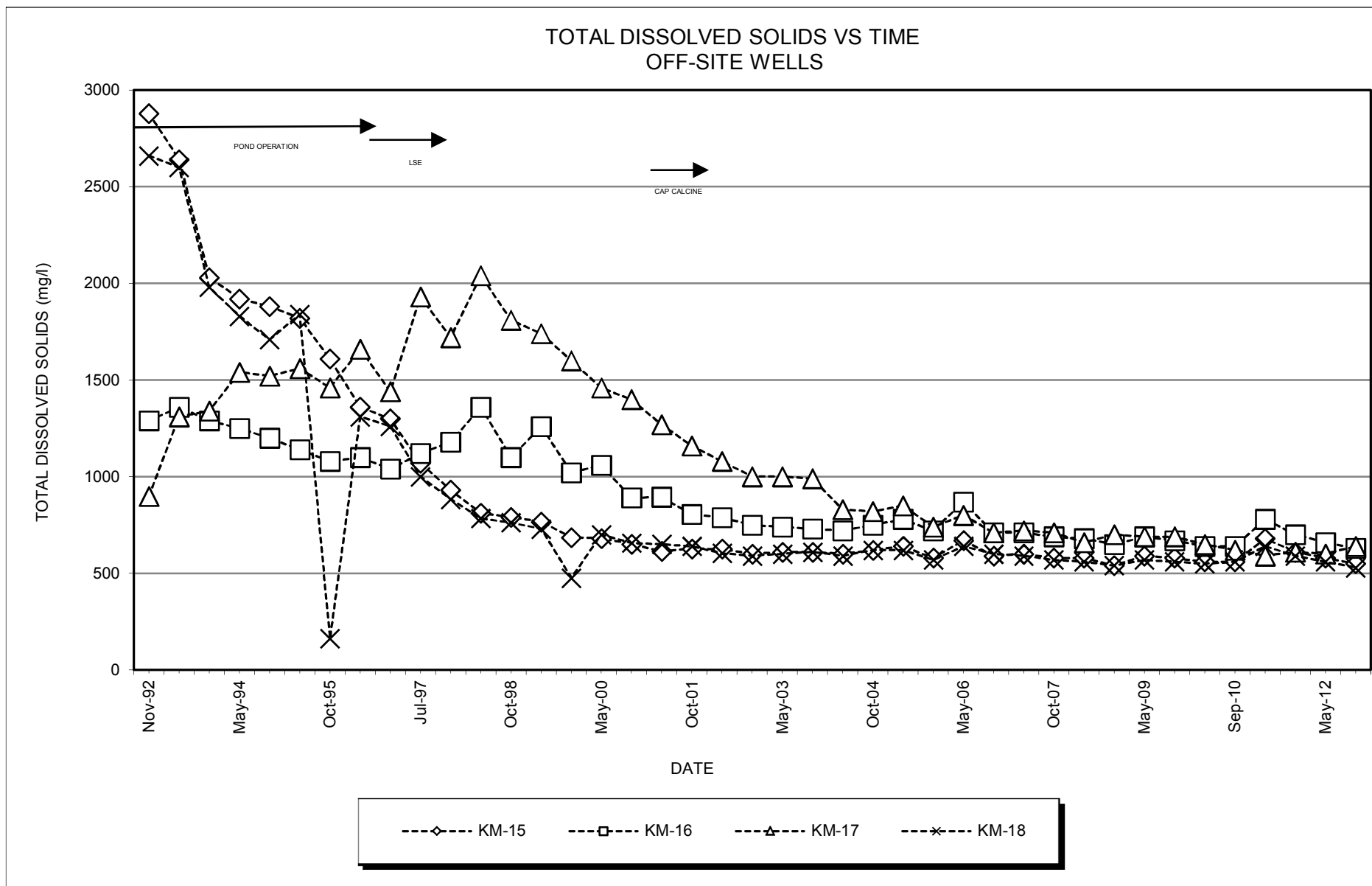


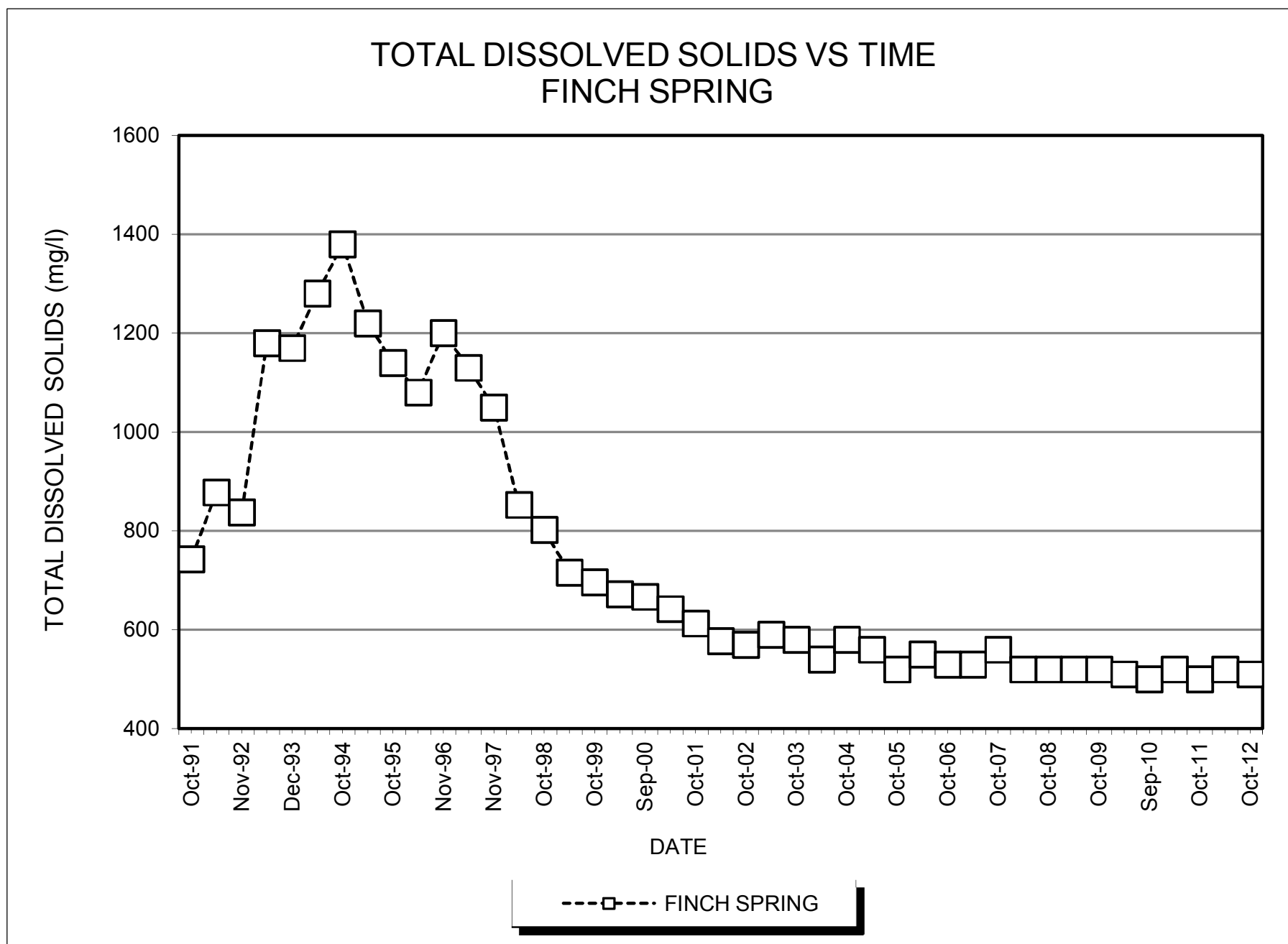


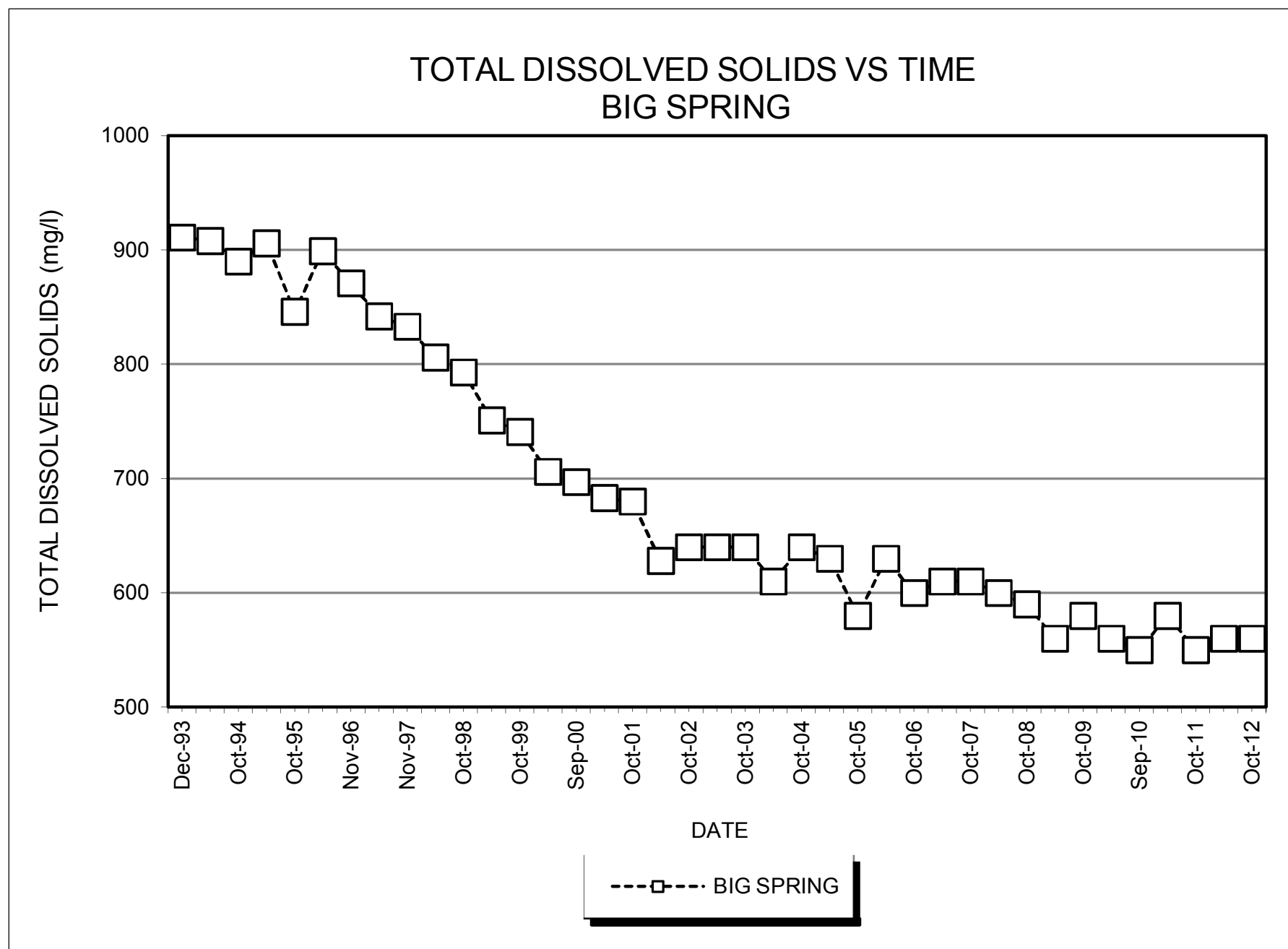


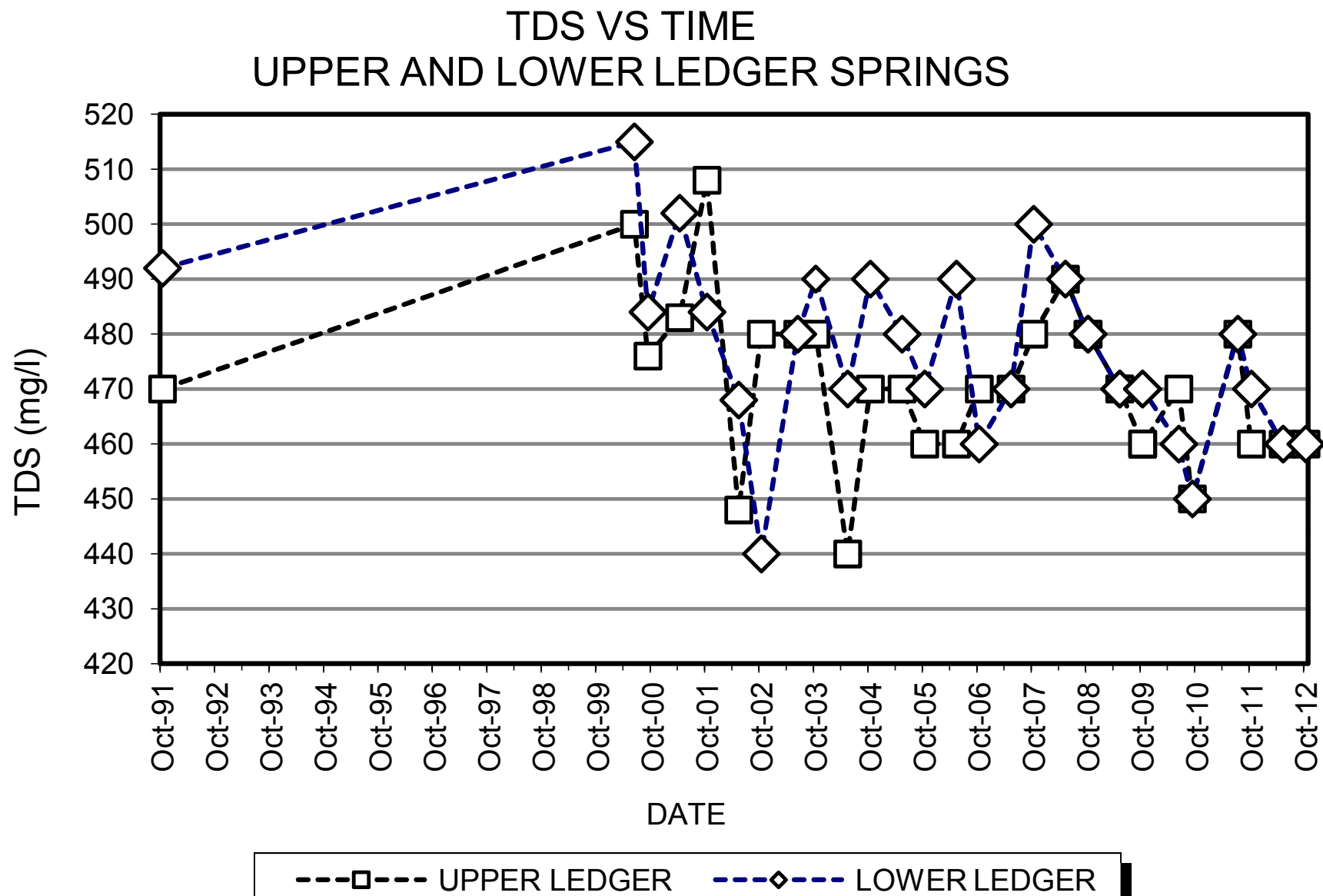


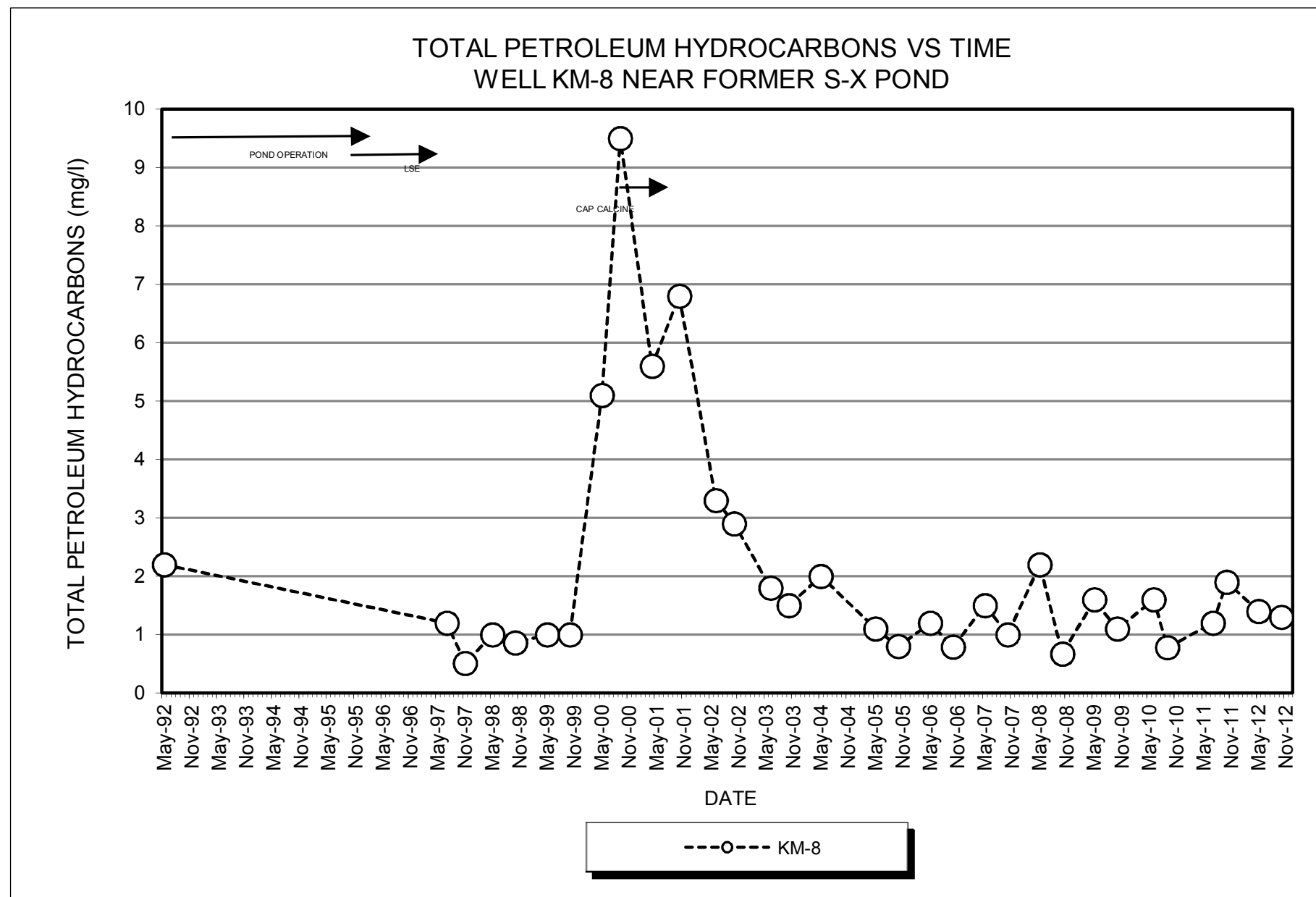








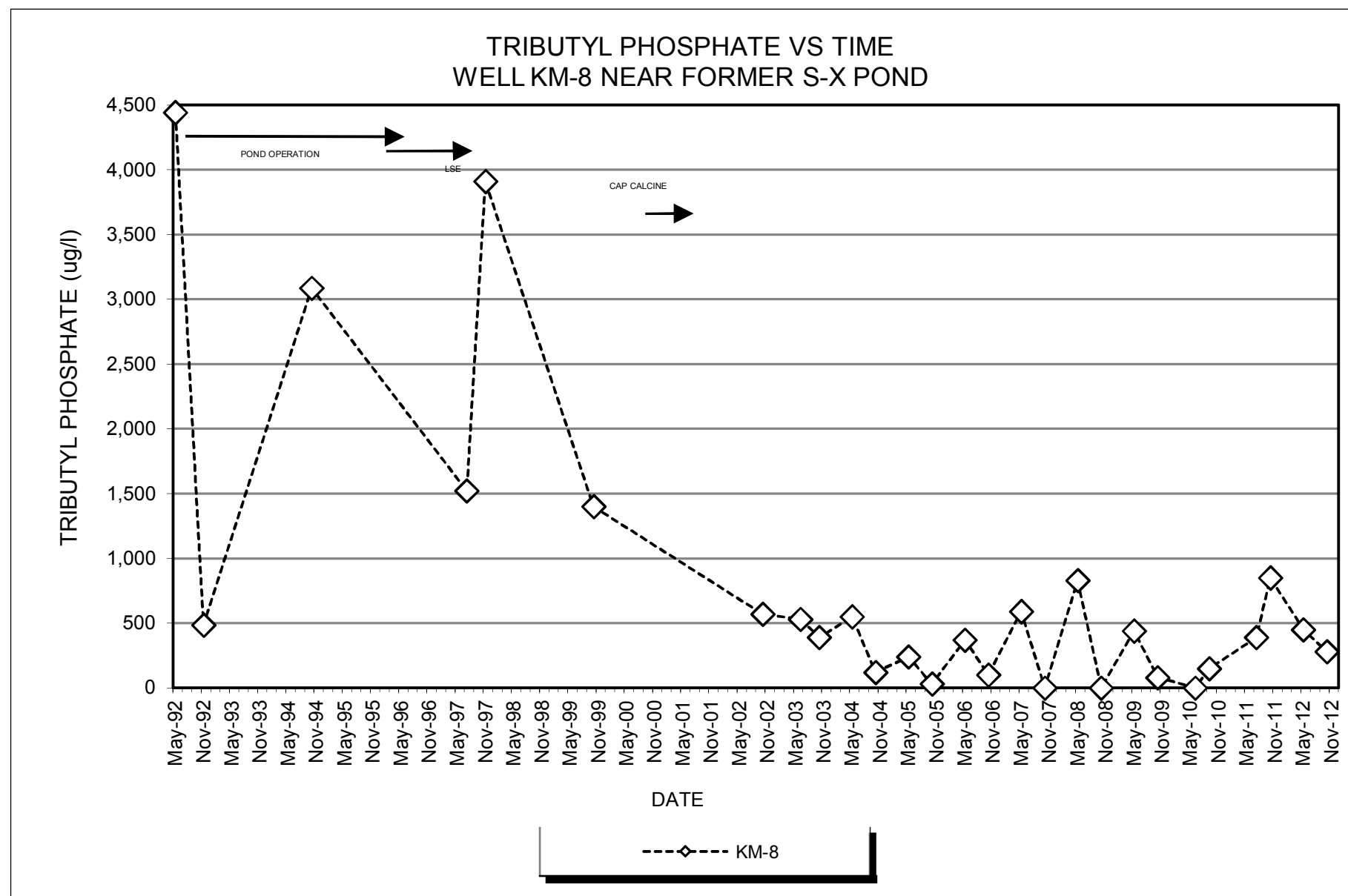




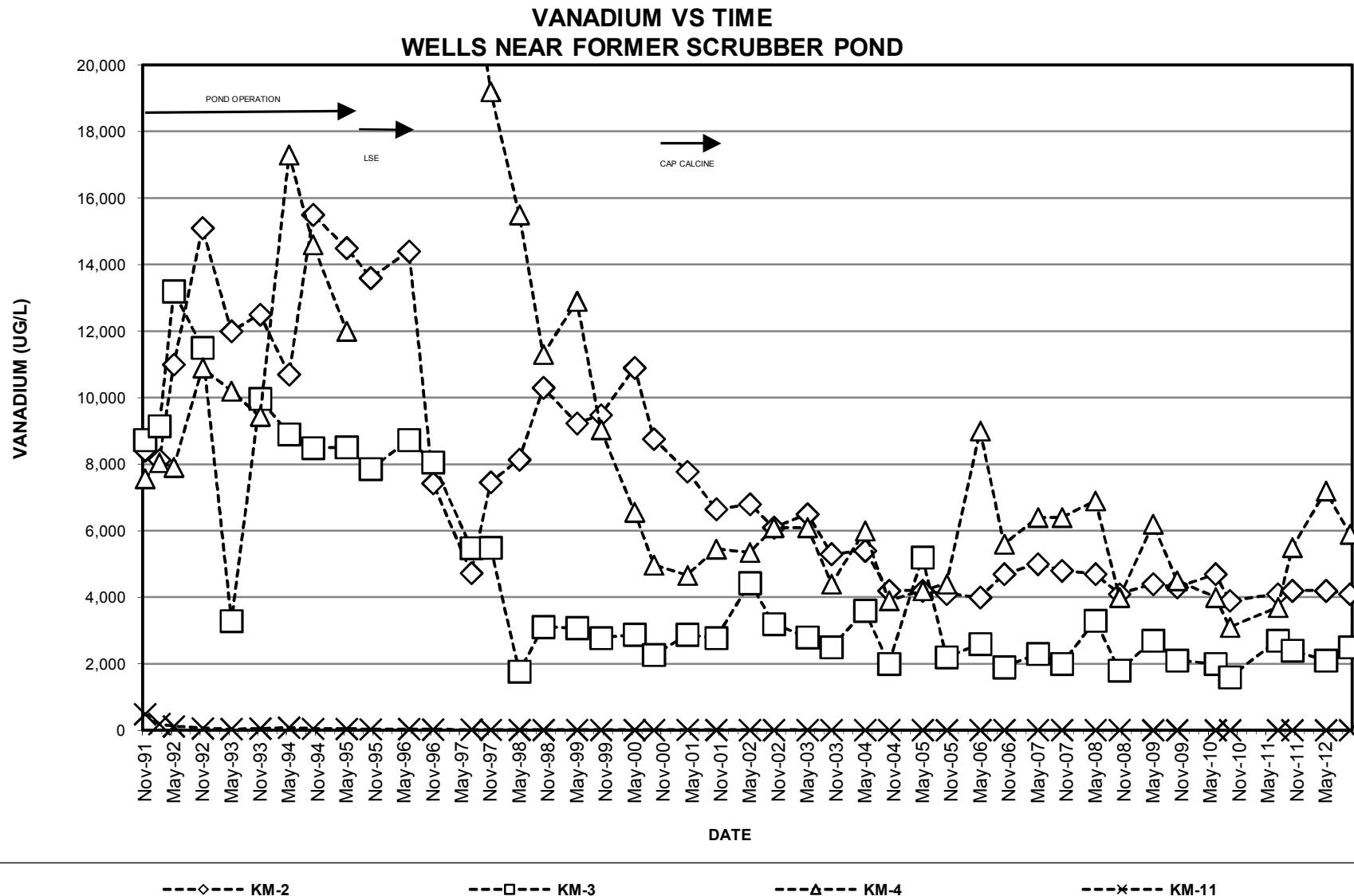
RBC FOR TPH IS 0.73 mg/l

KM-8 IS A POC WELL

1999 VALUES LESS THAN DETECTION



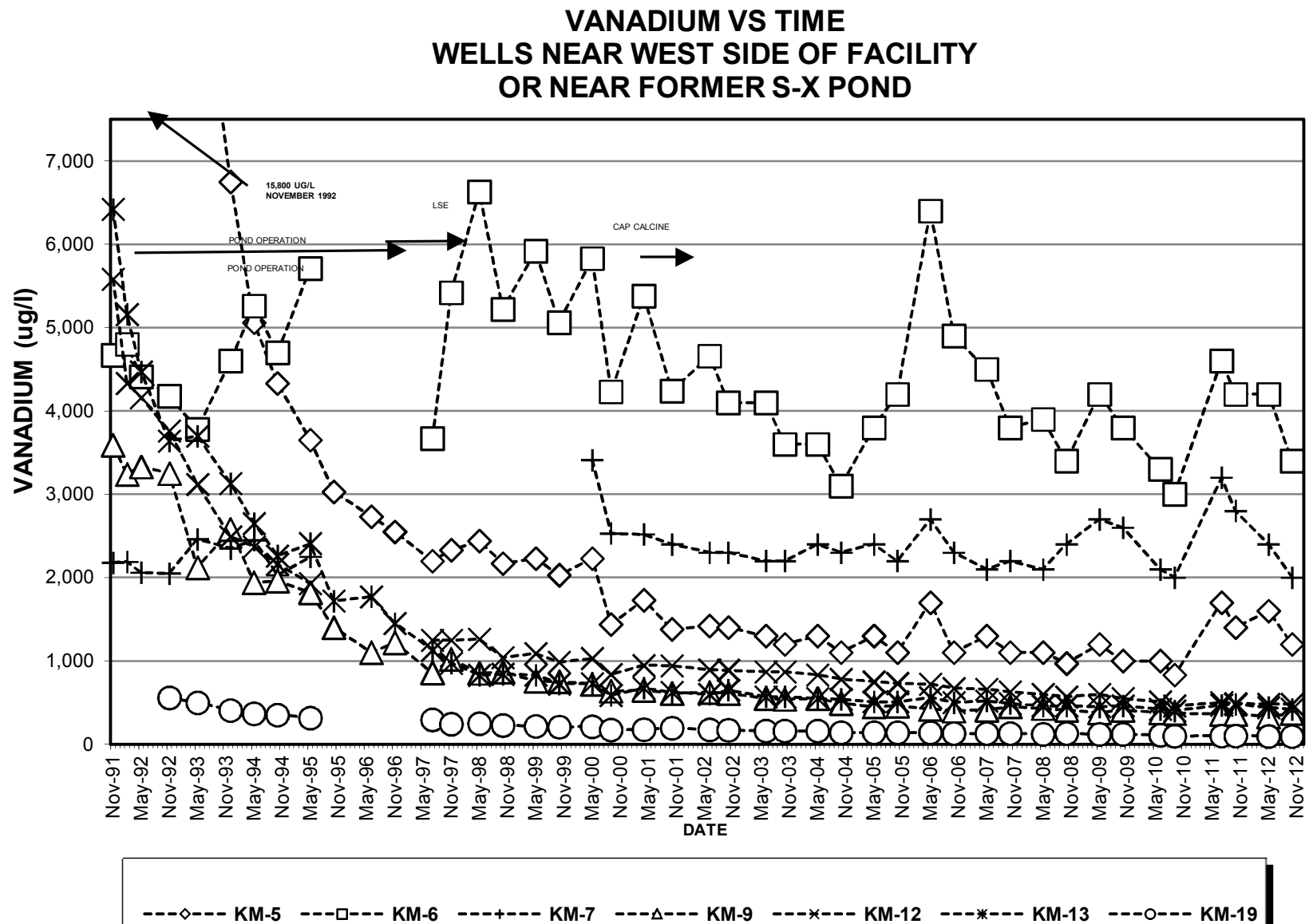
RBC FOR TRIBUTYL PHOSPHATE IS 180 ug/l
KM-8 IS A POC WELL
VALUES ESTIMATED AS DETECTED



RBC FOR VANADIUM IS 260 ug/l

KM-2, KM-3, KM-11 ARE POC WELLS

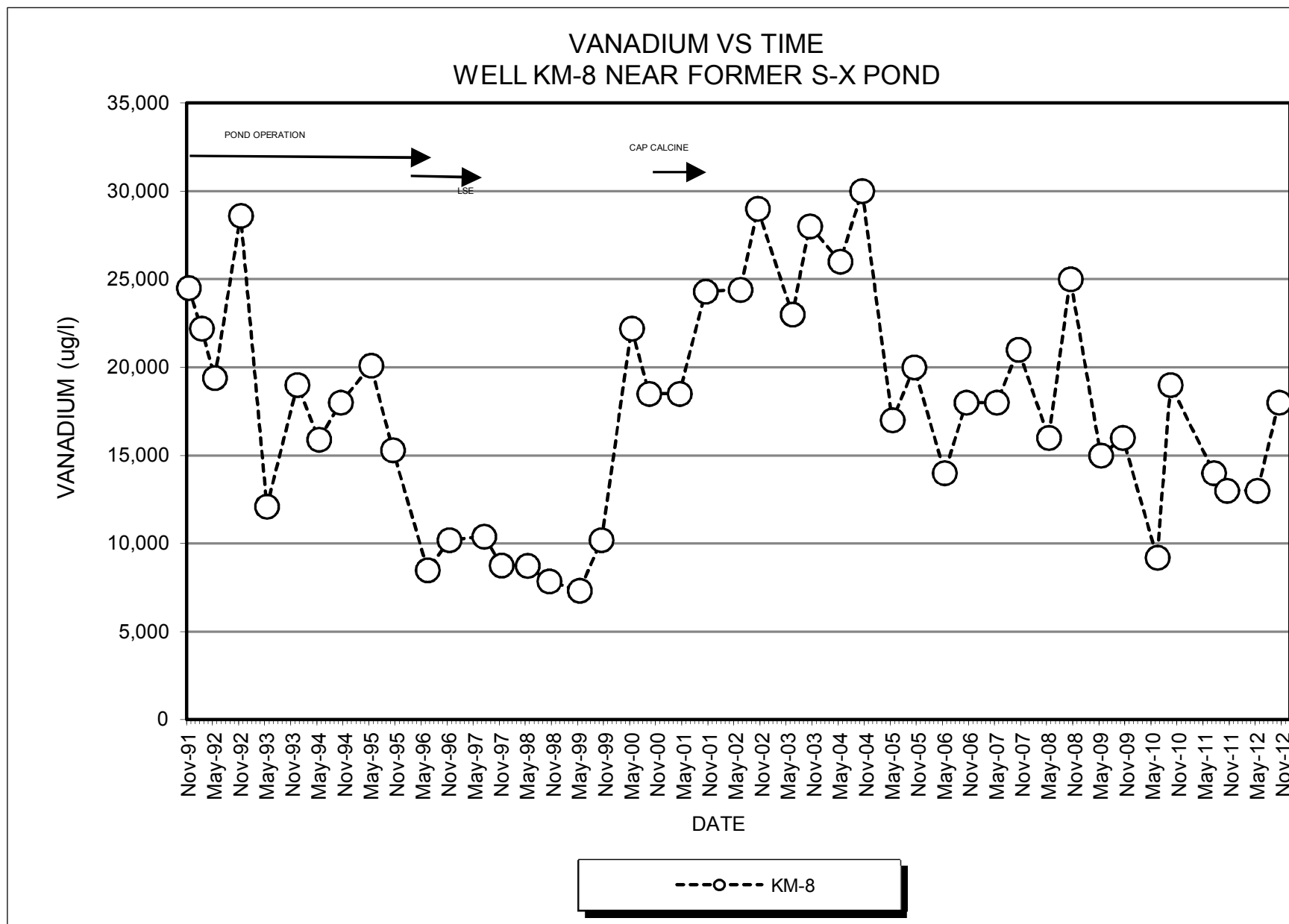
VALUES LESS THAN DETECTION ARE PLOTTED AT DETECTION LIMIT



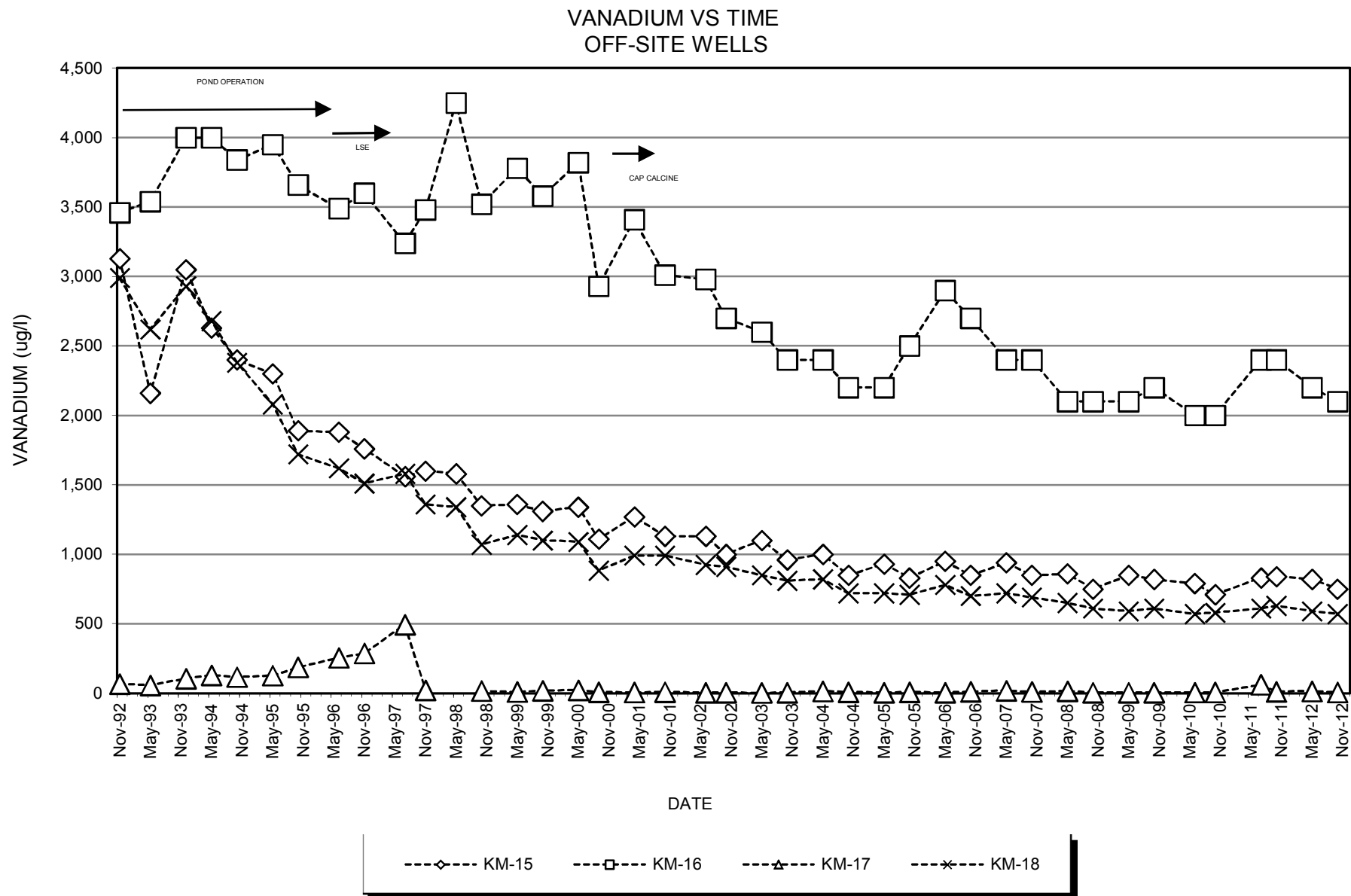
RBC FOR VANADIUM IS 260 ug/l

KM-2, KM-3, KM-11 ARE POC WELLS

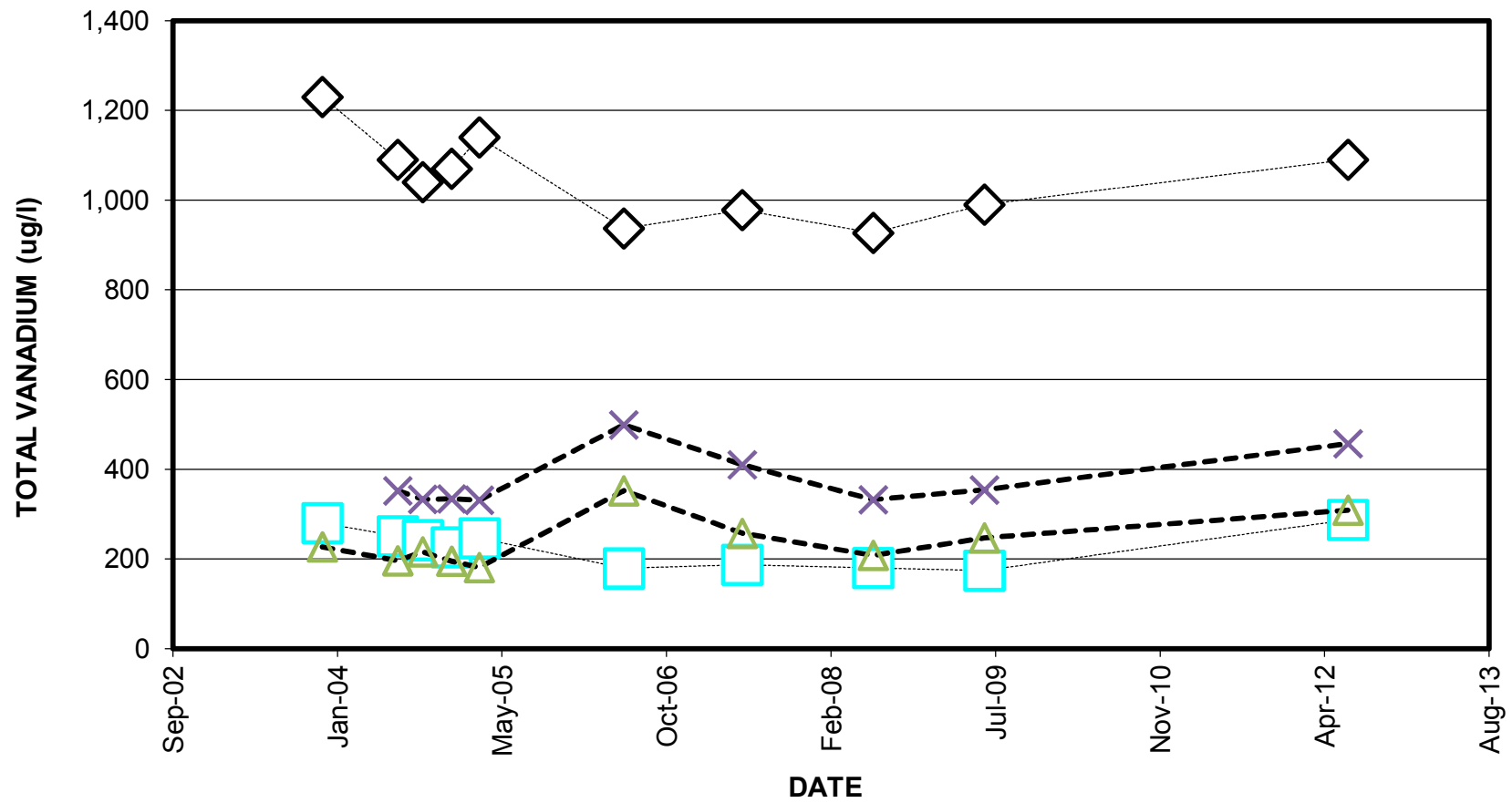
VALUES LESS THAN DETECTION ARE PLOTTED AT DETECTION LIMIT



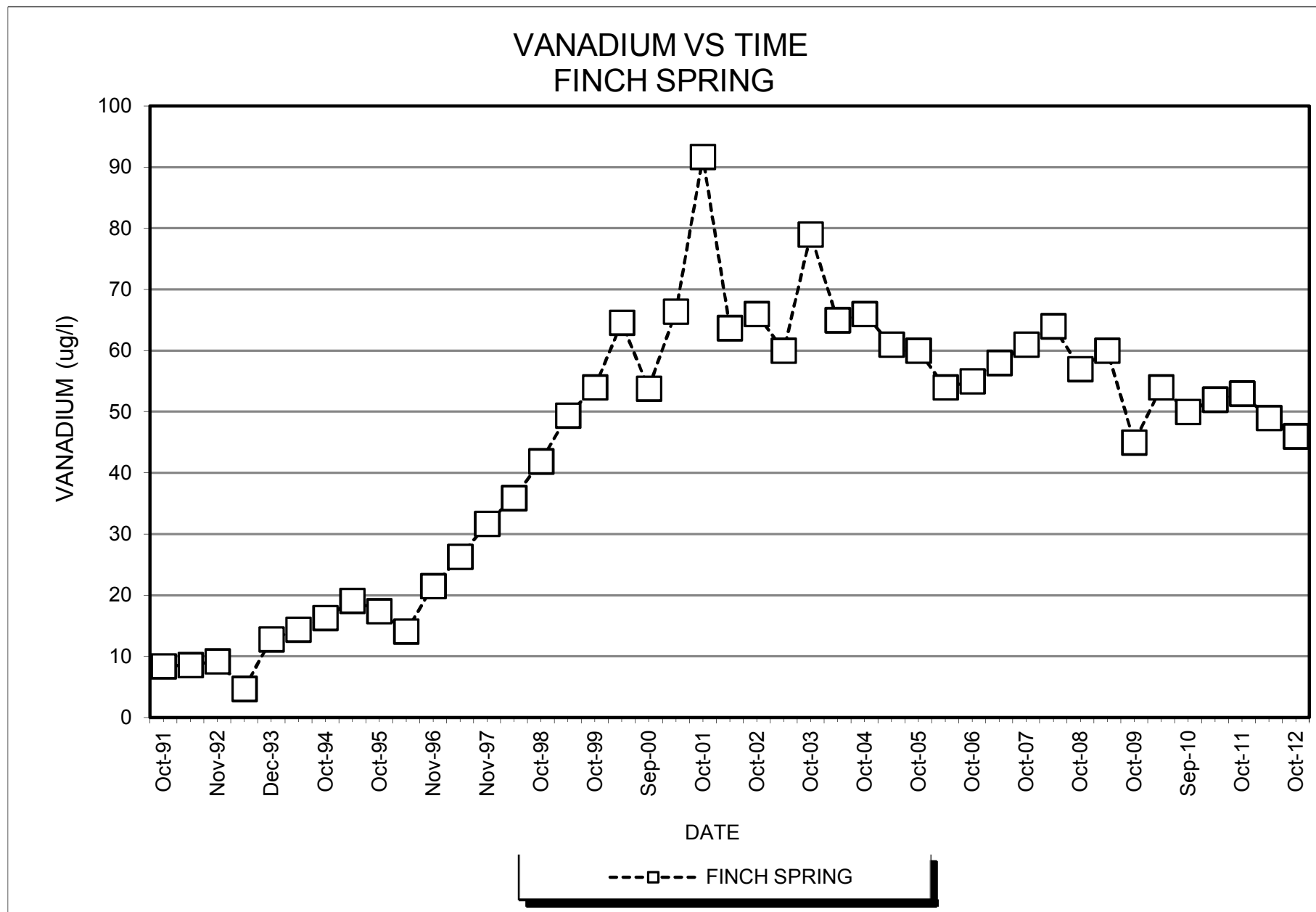
RBC FOR VANADIUM IS 260 ug/l
KM-8 IS A POC WELLS

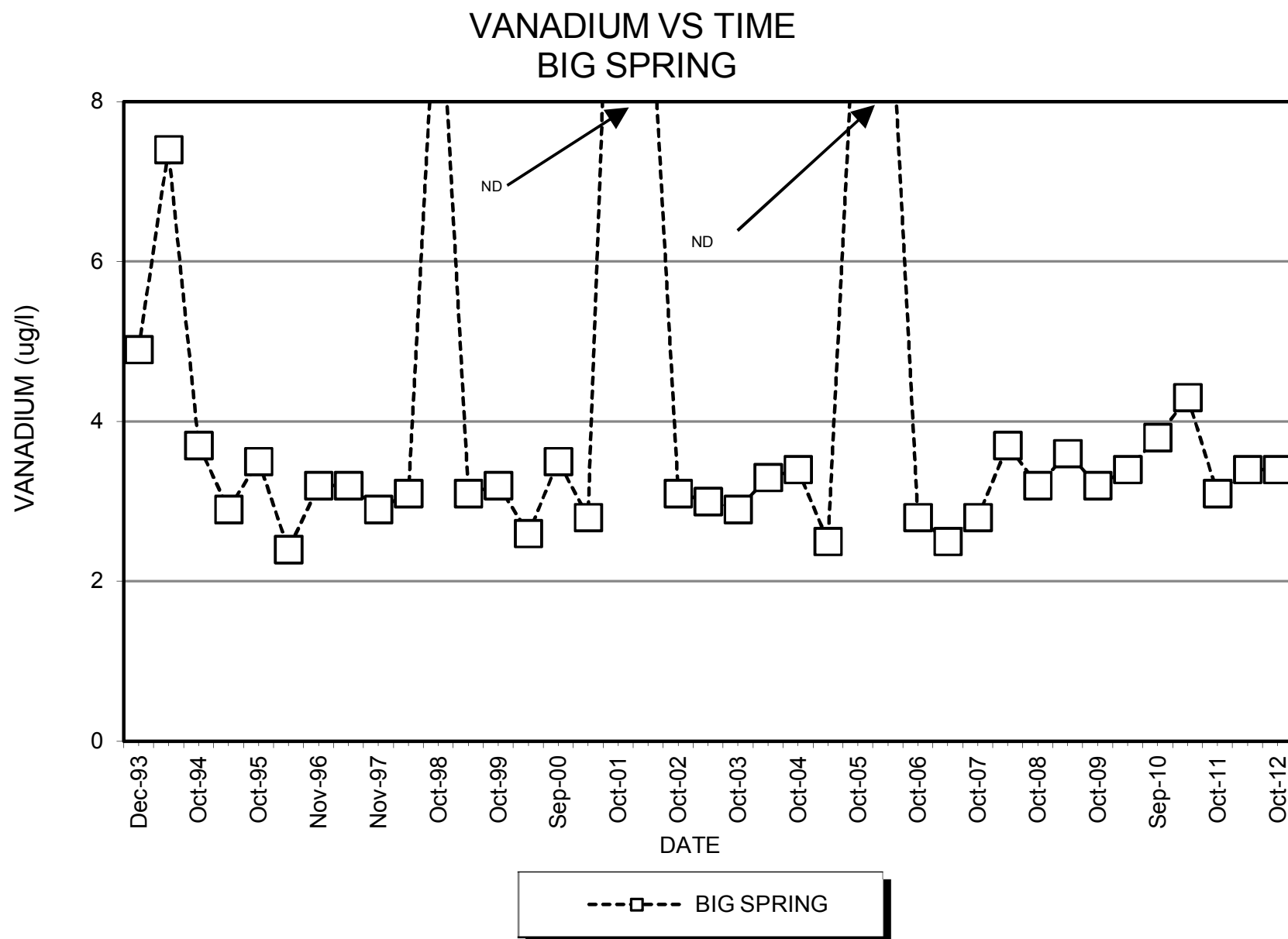


VANADIUM VS TIME - EVERGREEN WELLS



EV-1 EV-2 EV-3 EV-4

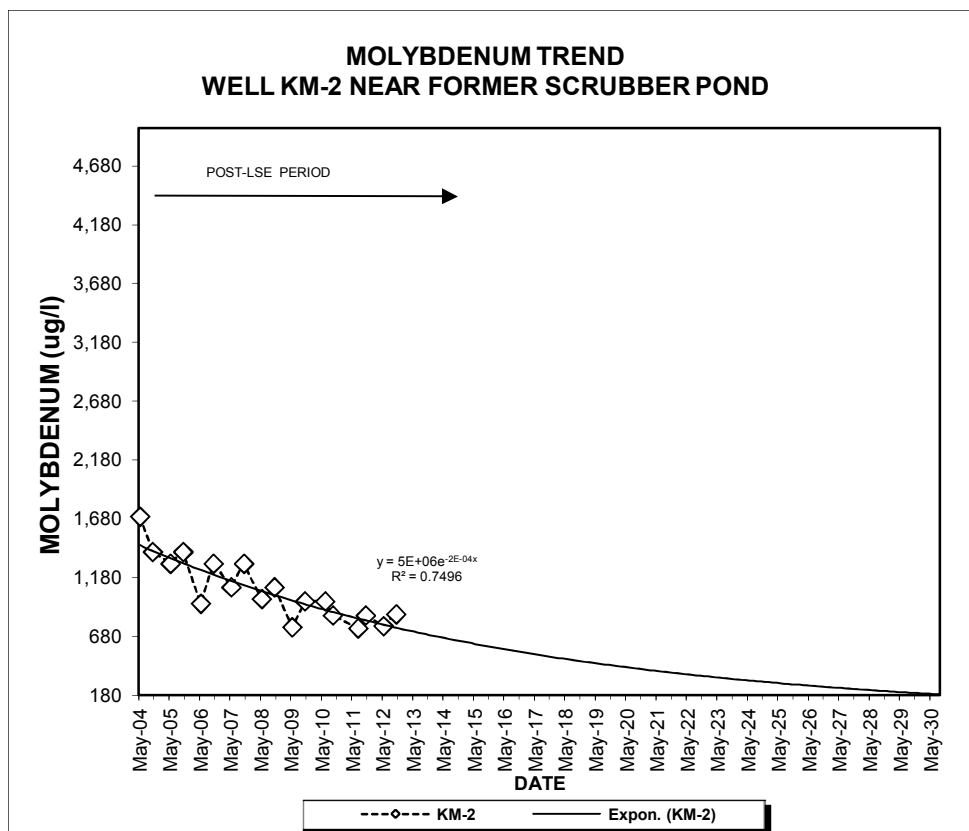
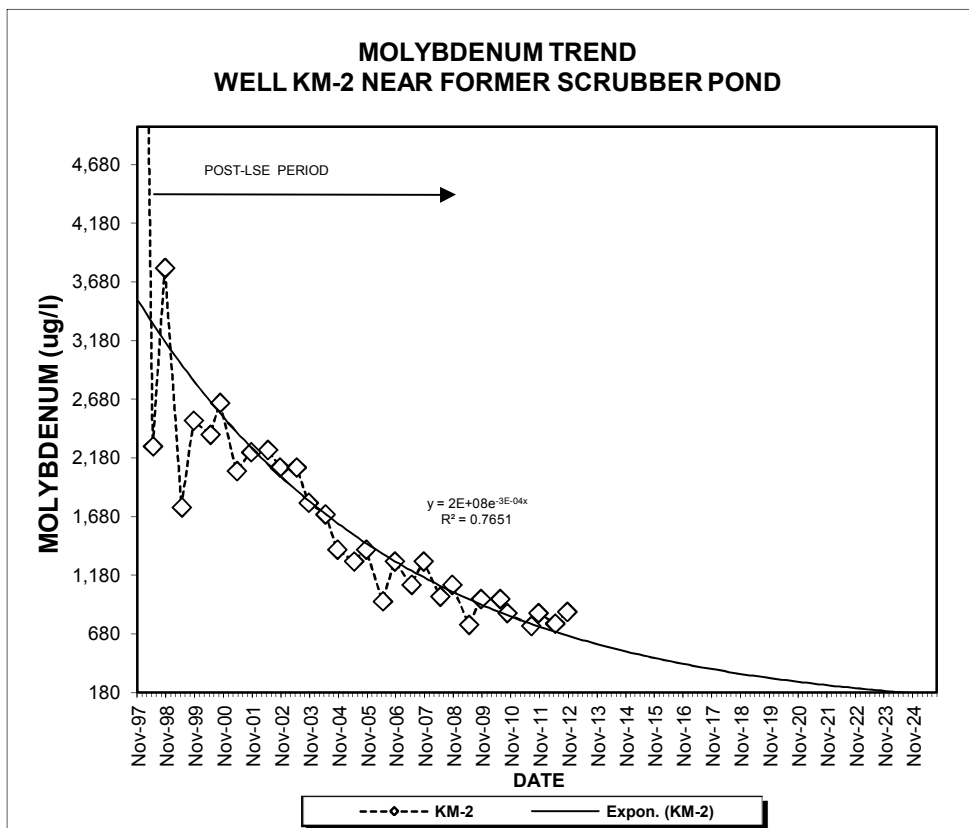


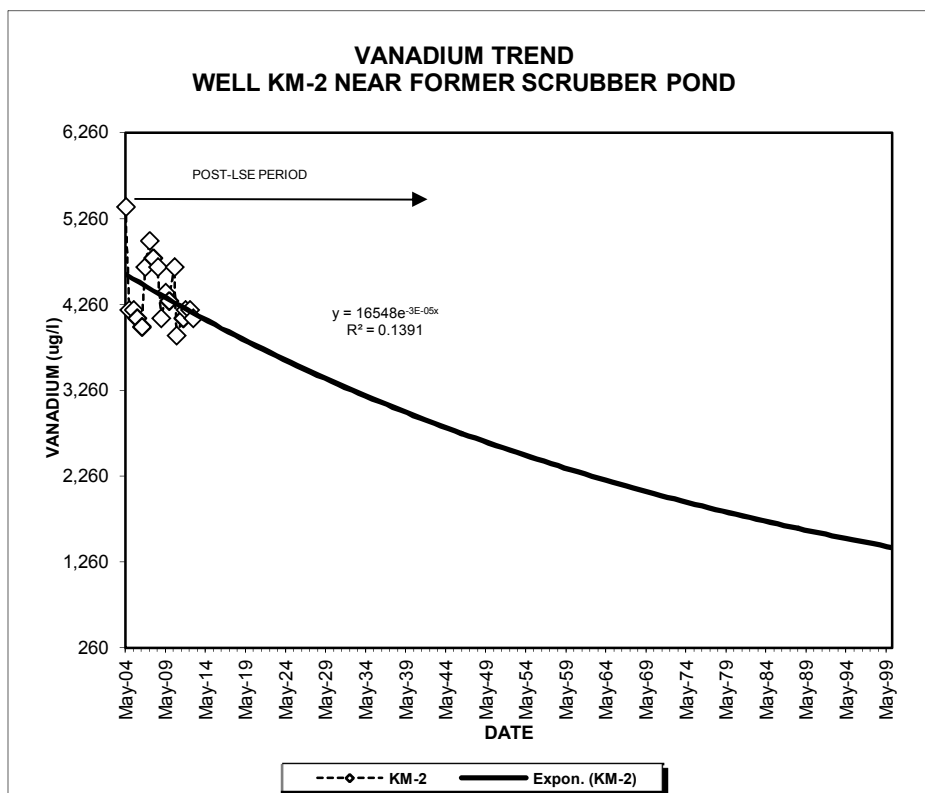
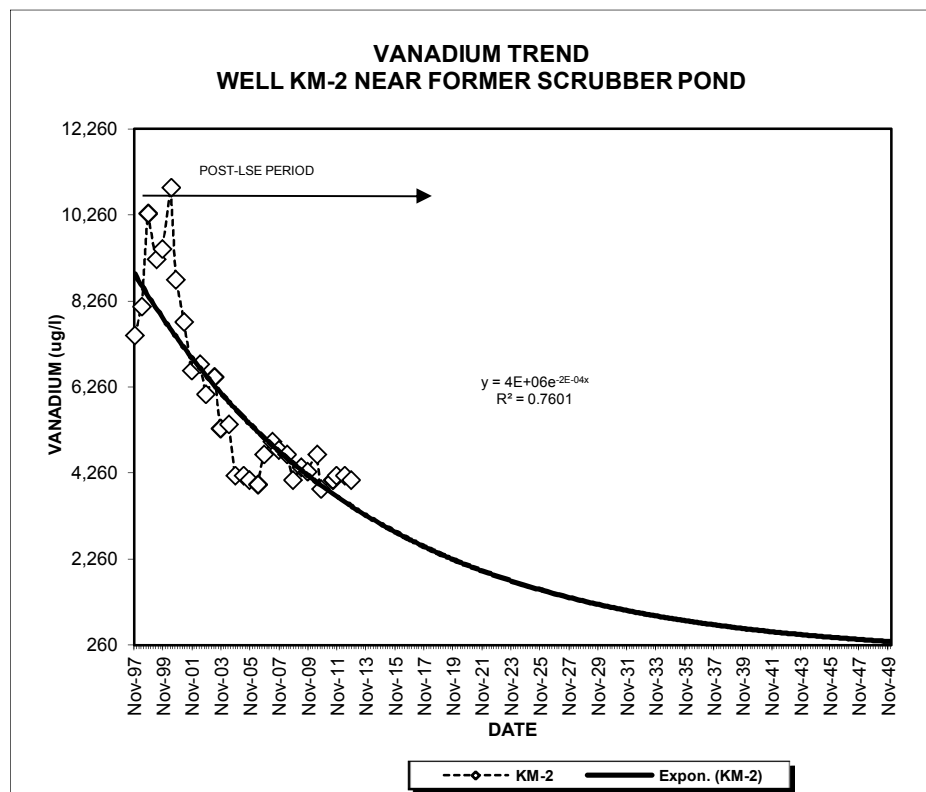


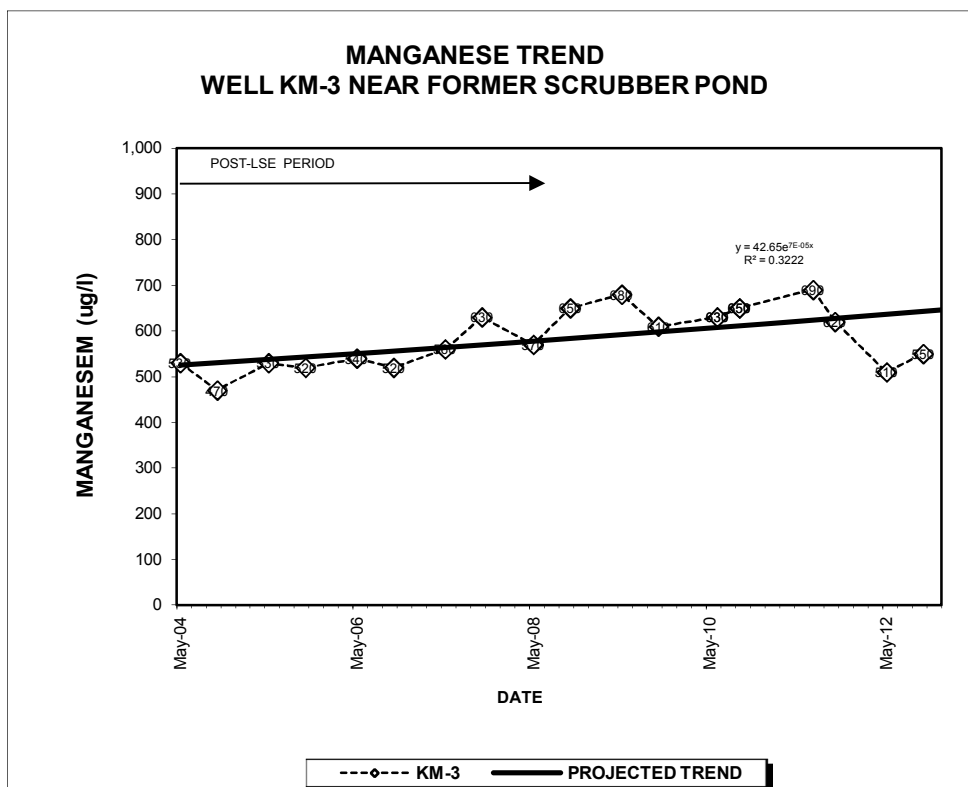
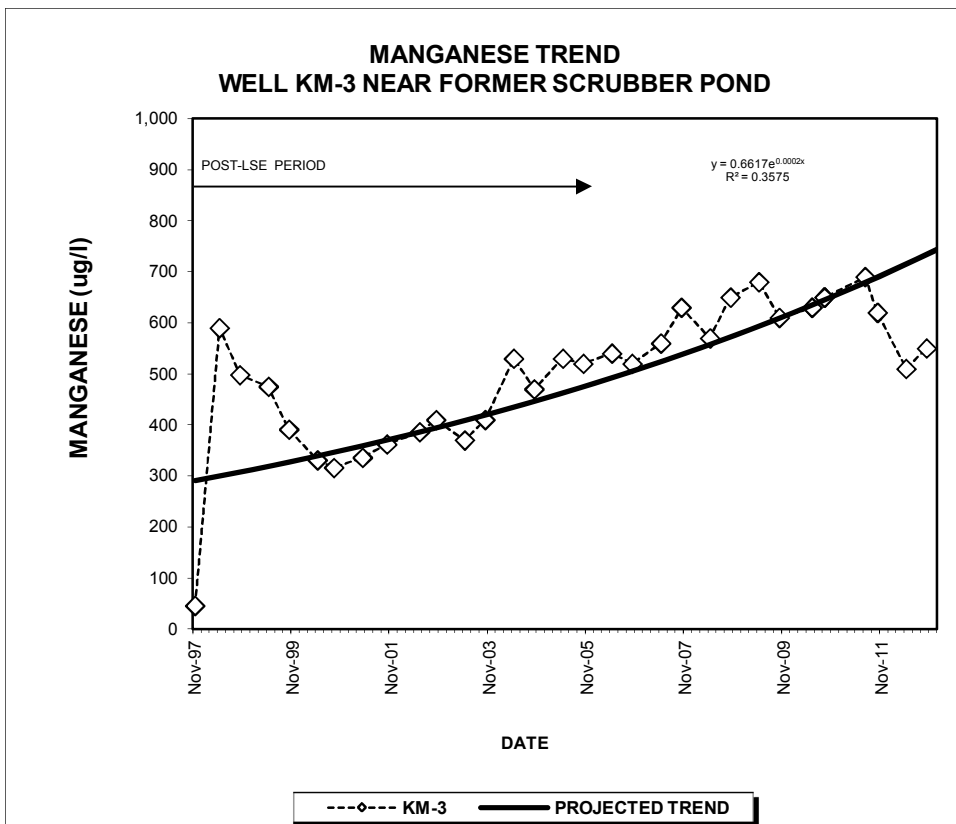
Values less than detection annotated on figure

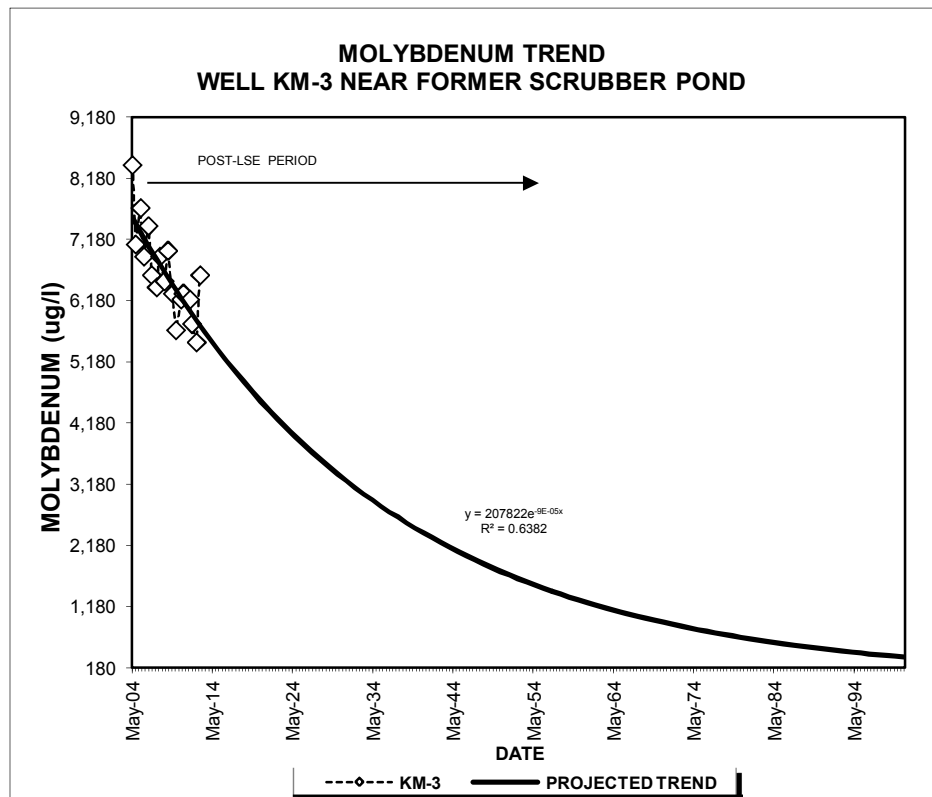
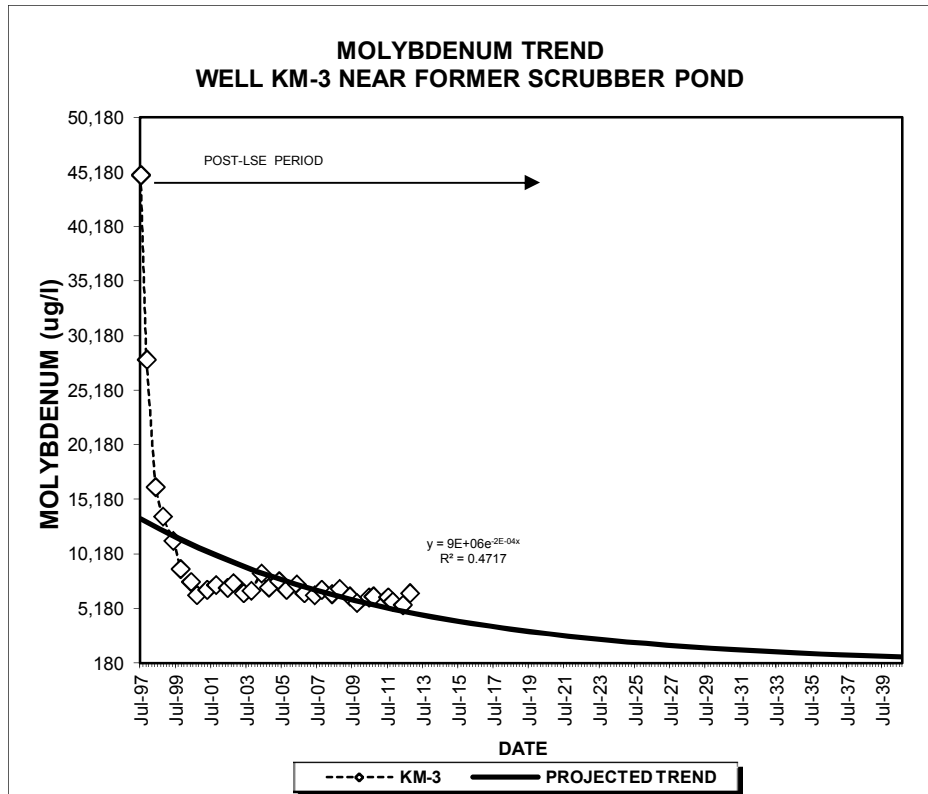
APPENDIX B

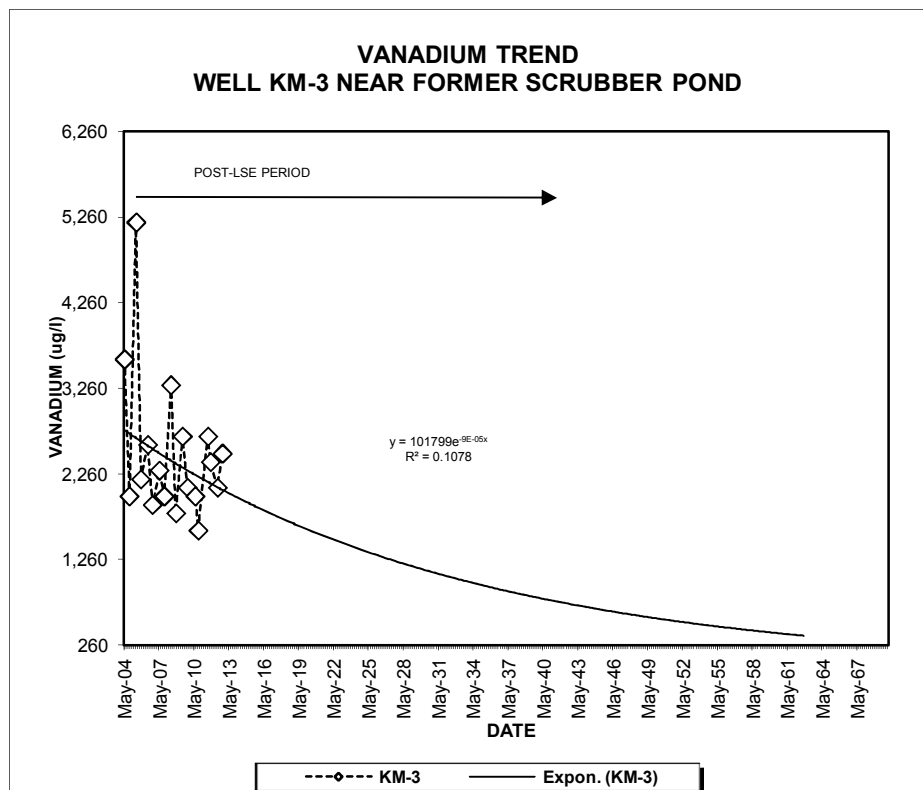
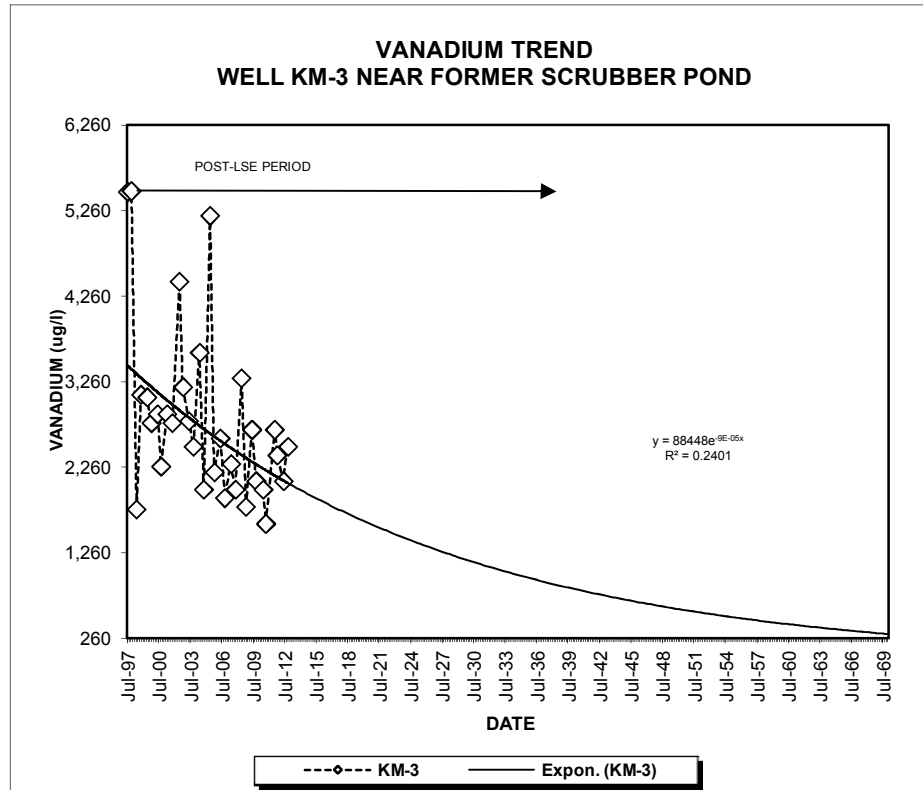
**COC CONCENTRATION TRENDS WITH TIME
AND PROJECTED TRENDS**

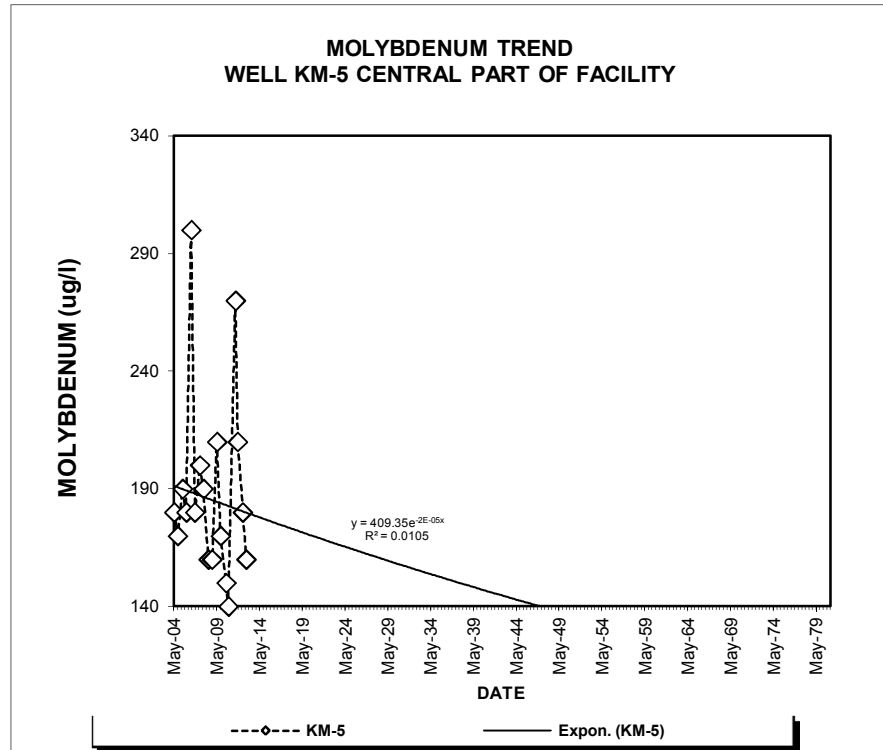
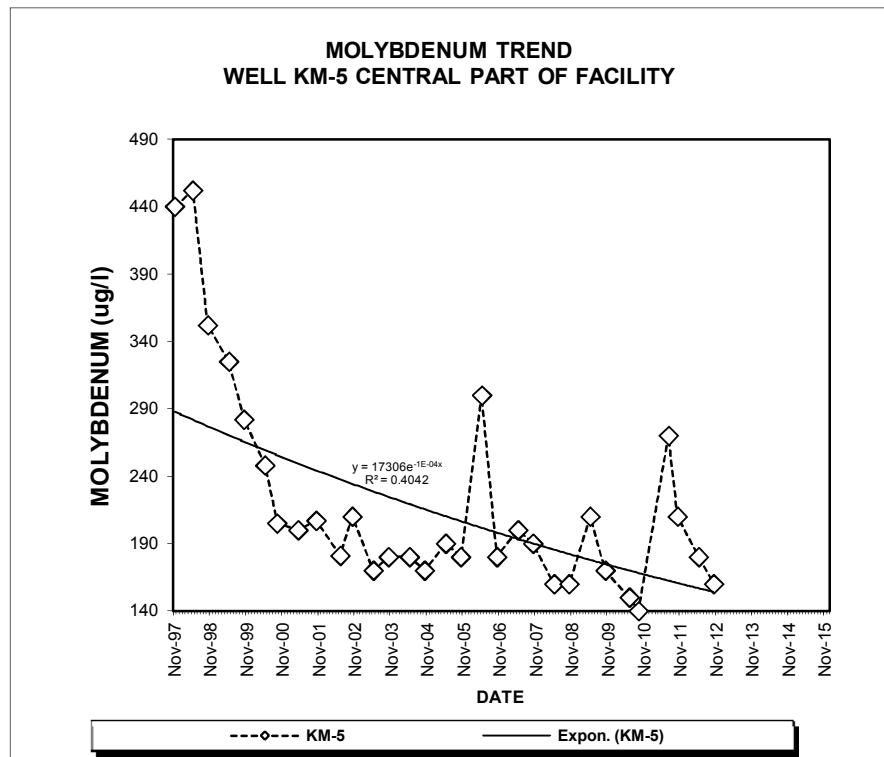


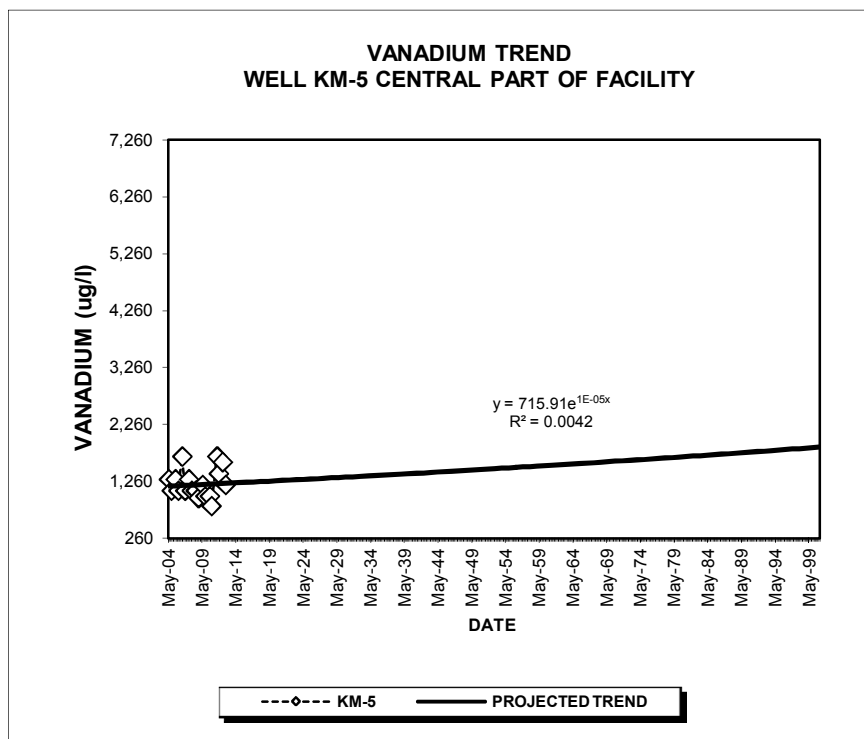
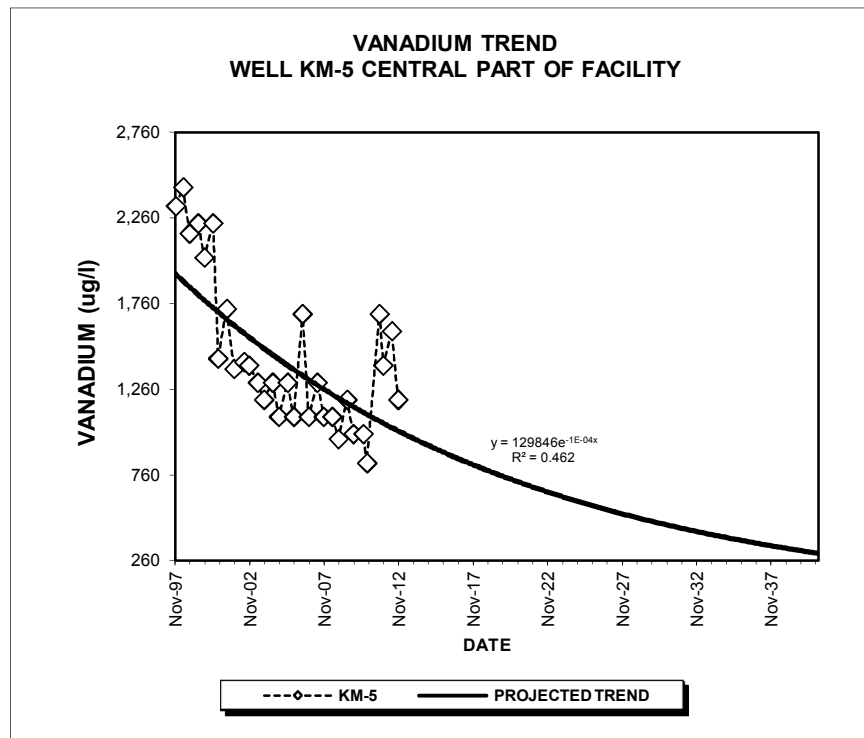


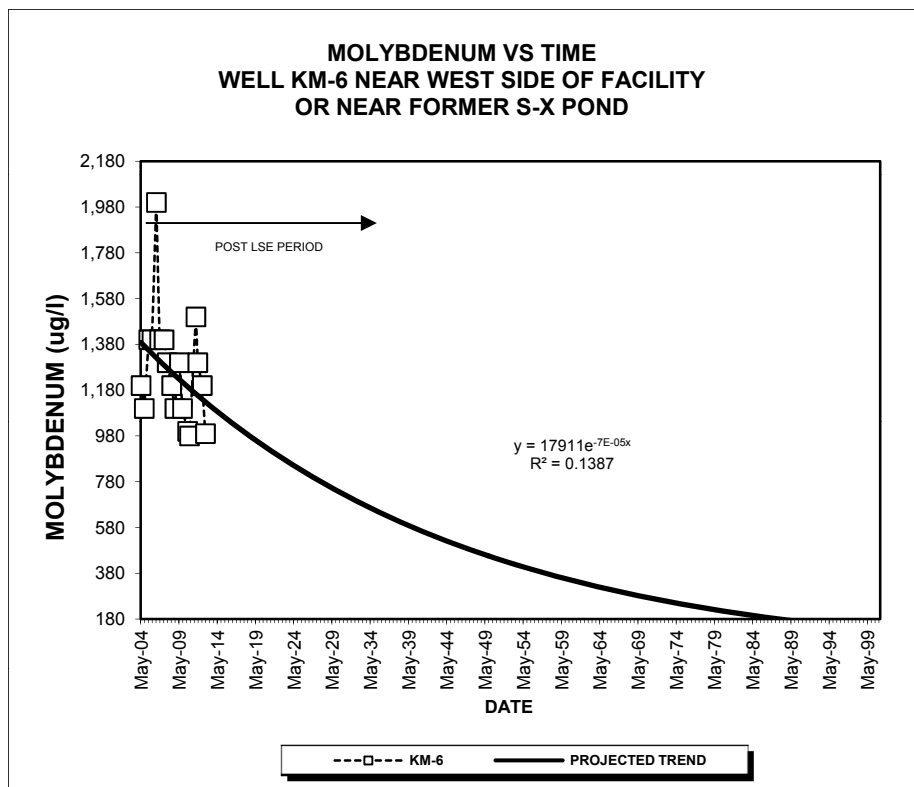
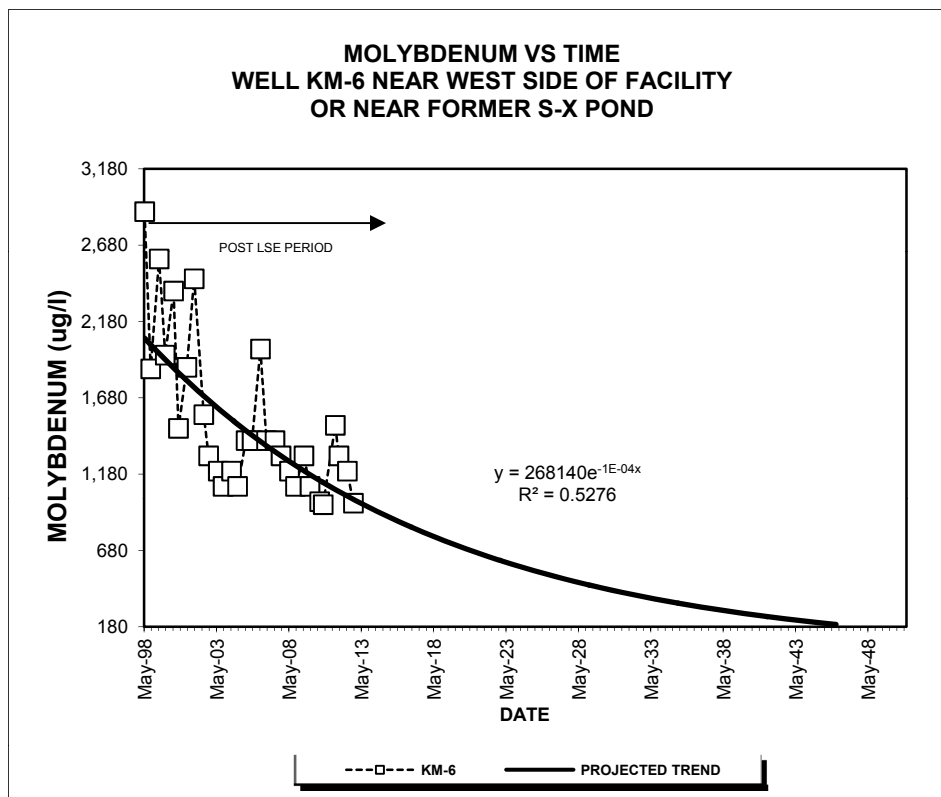


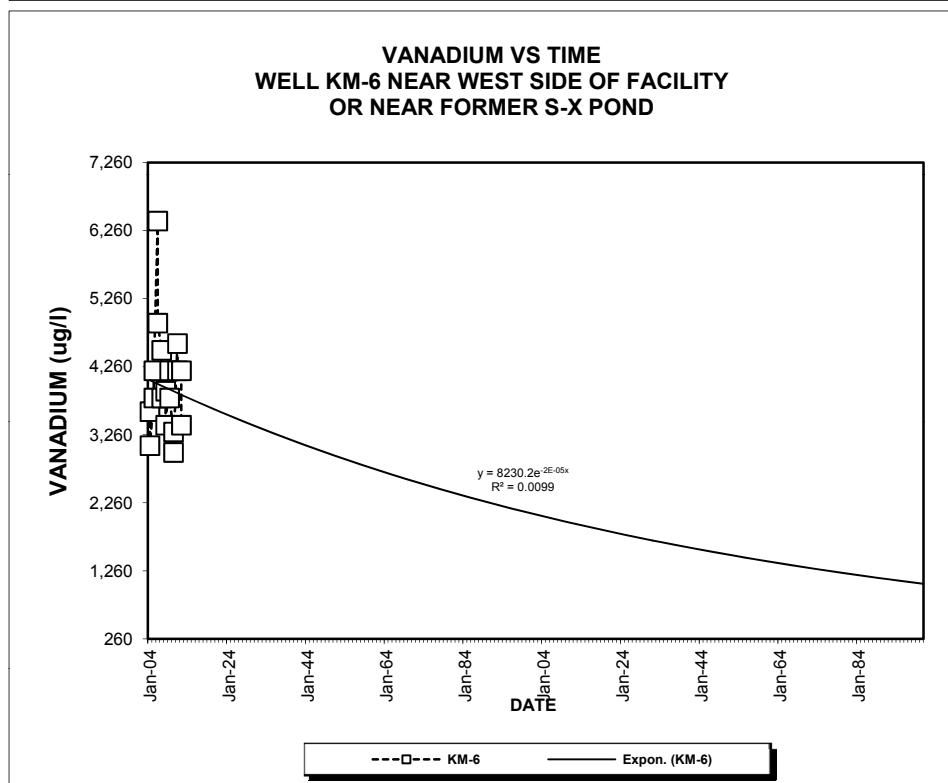
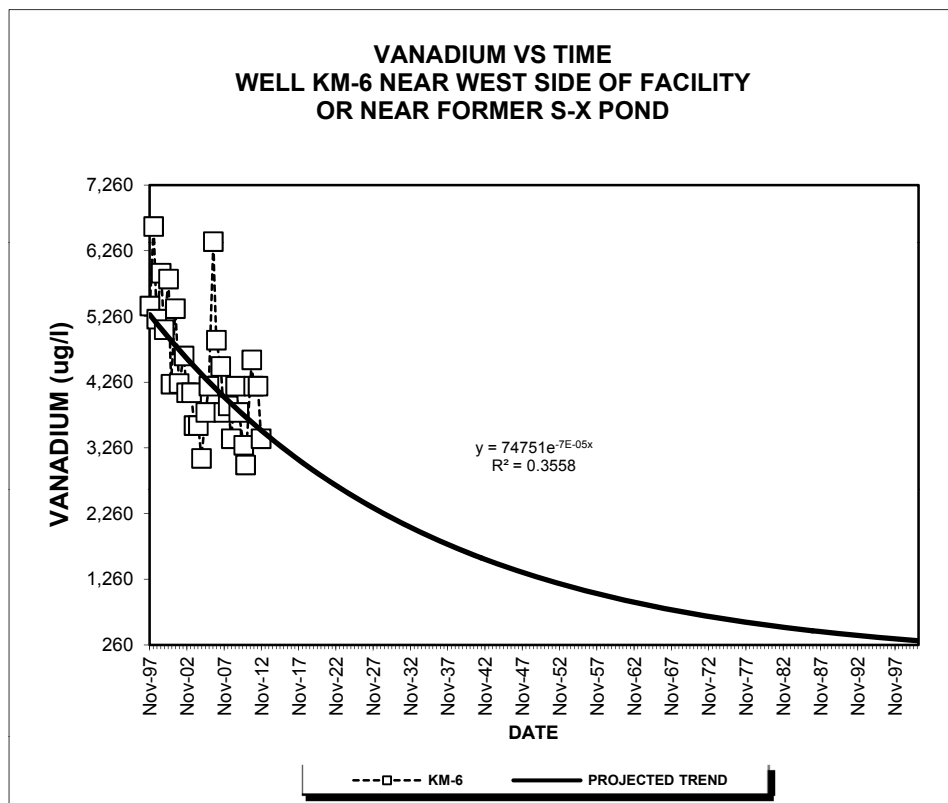


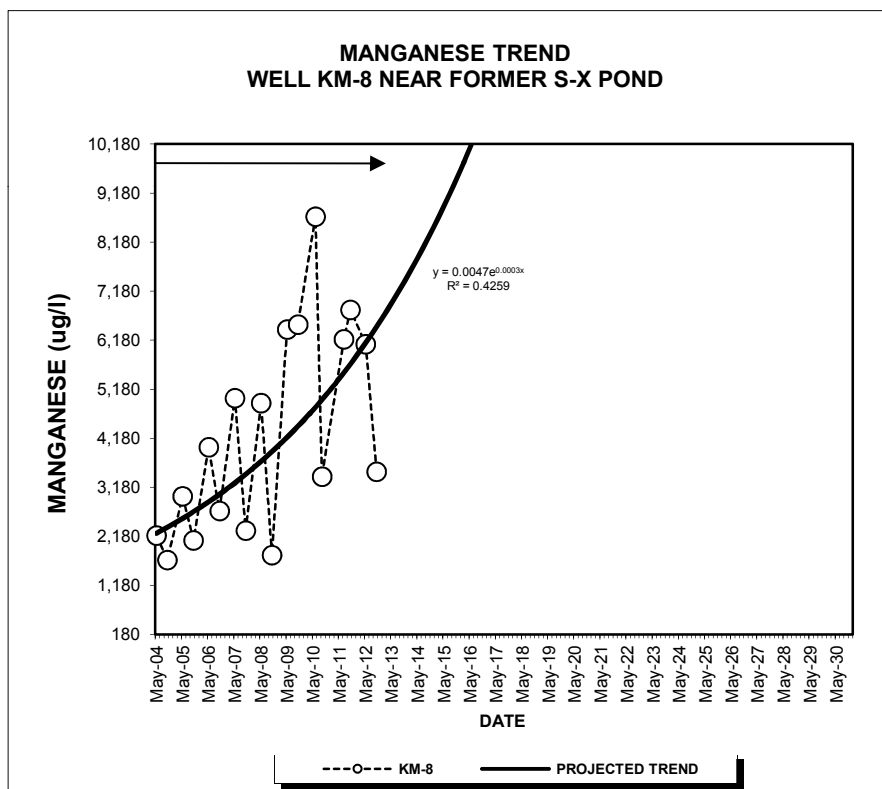
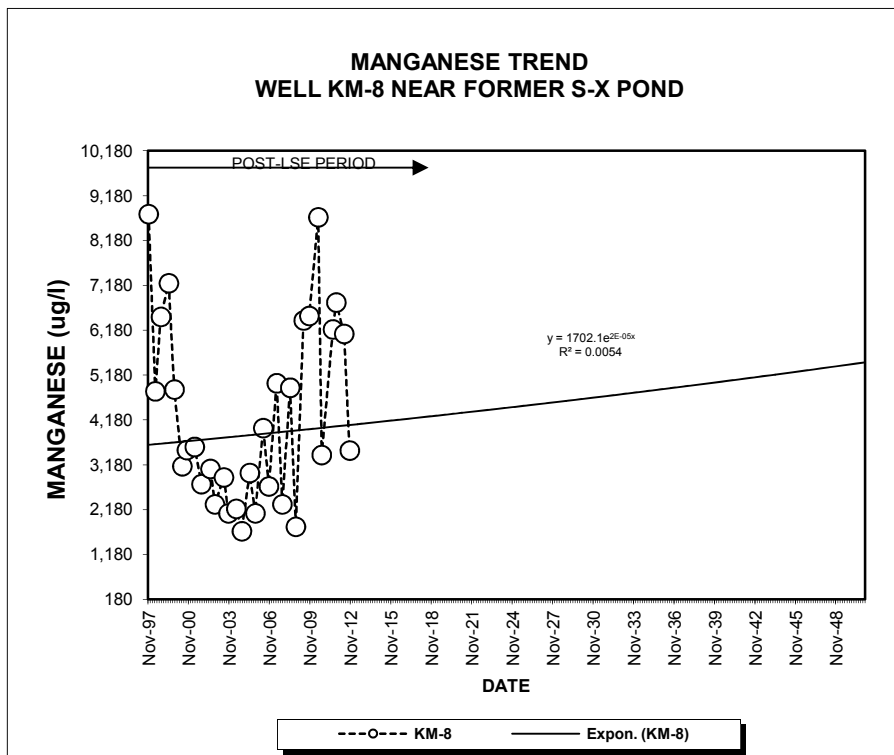


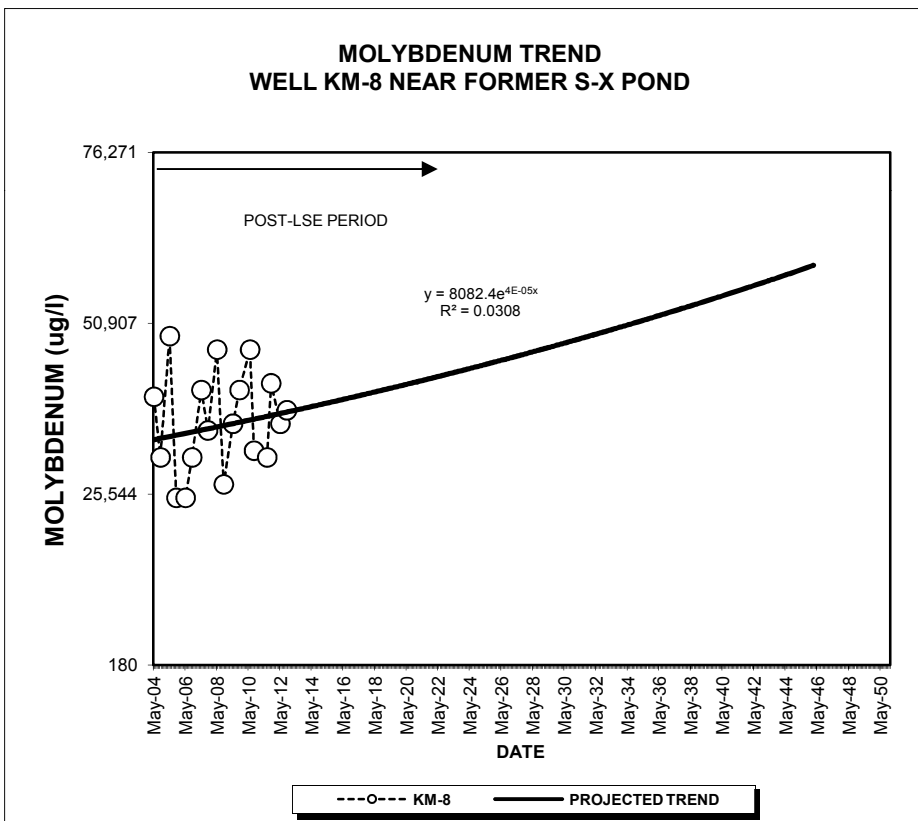
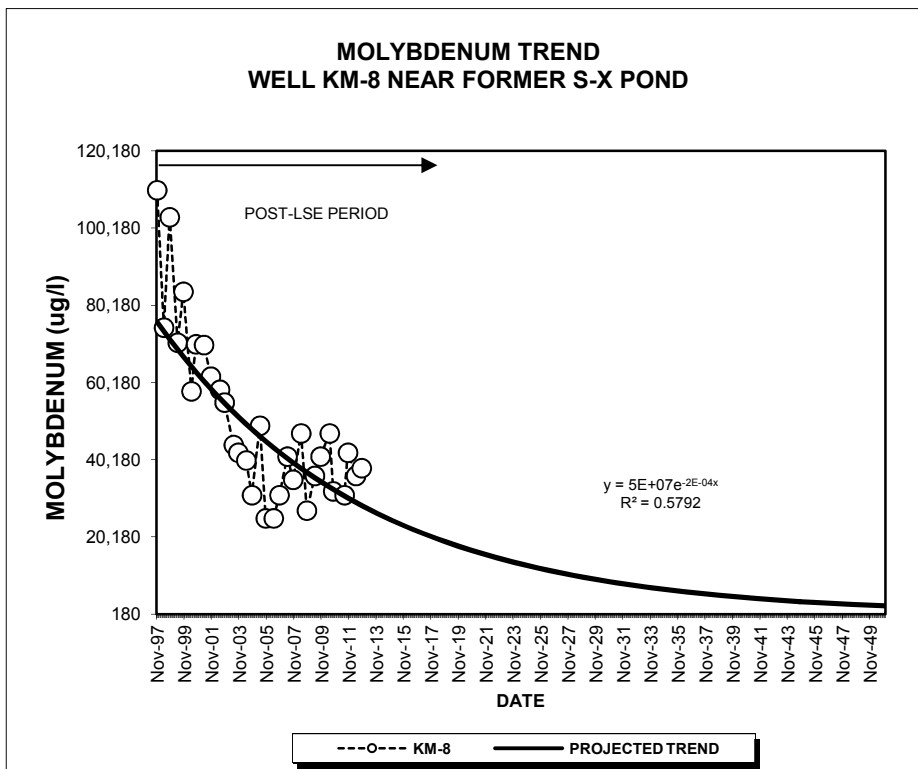


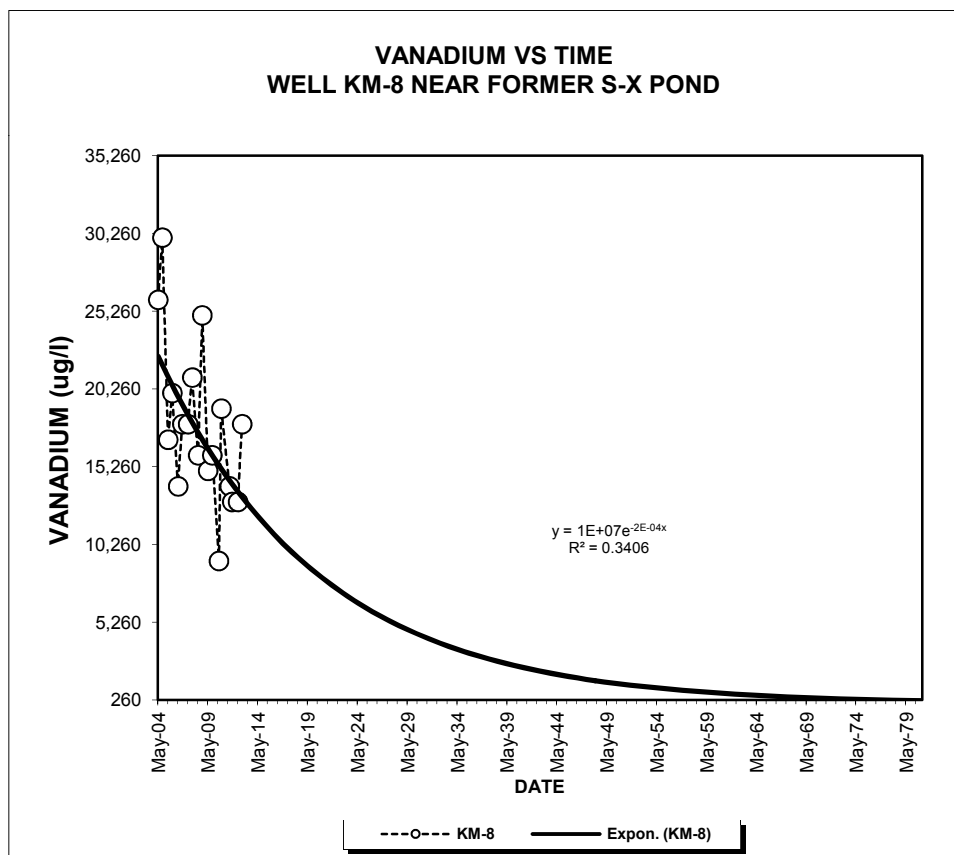
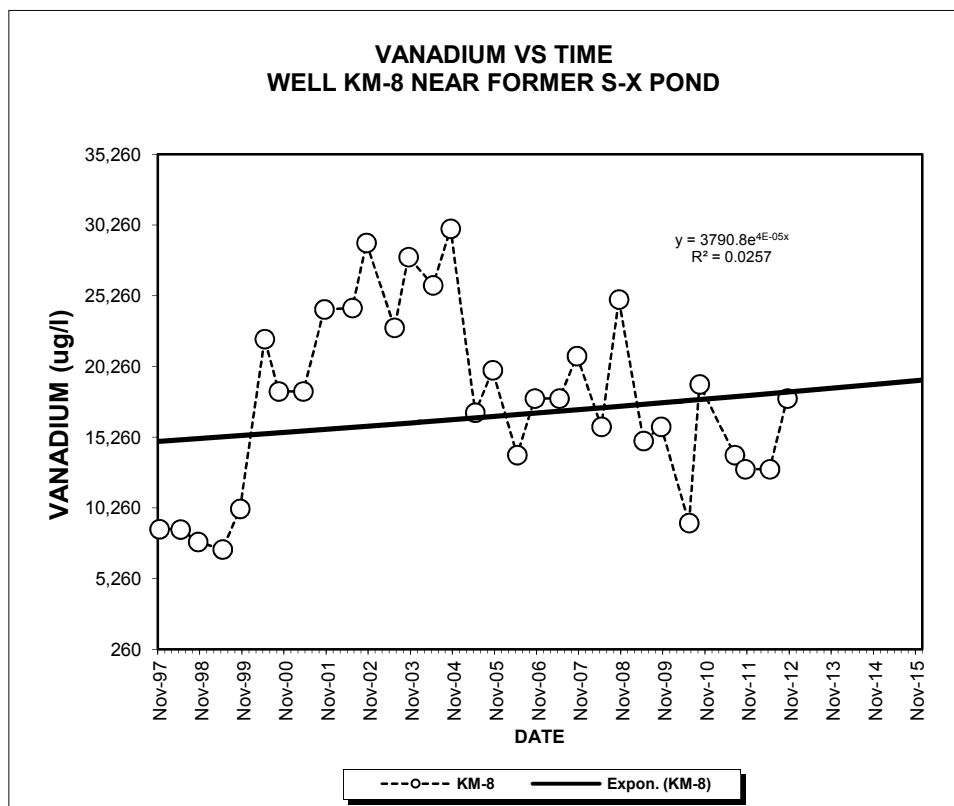


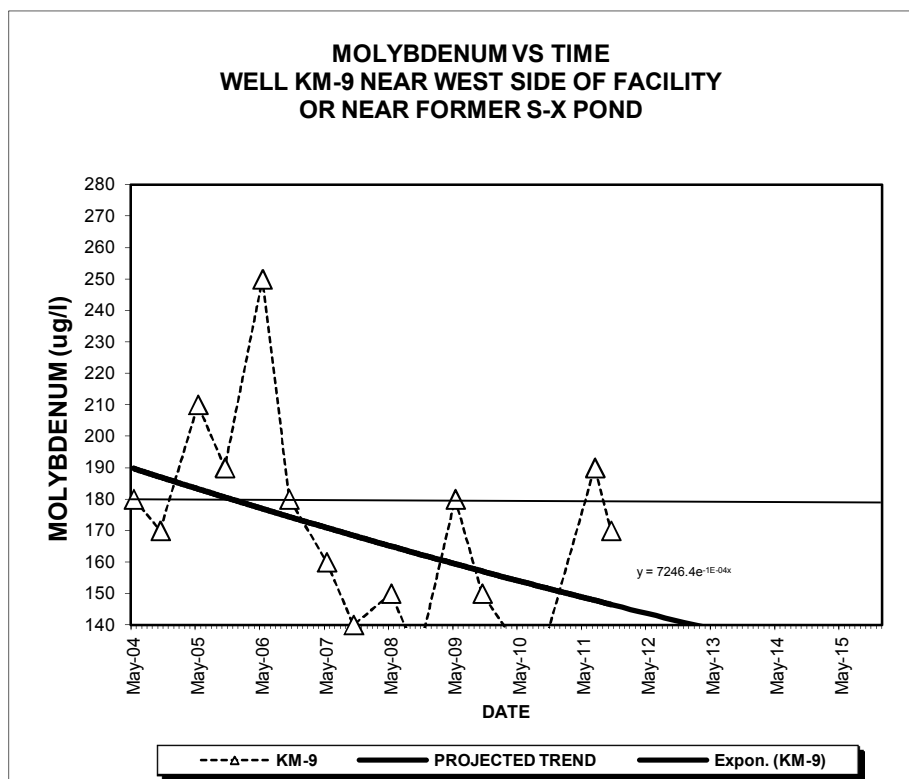
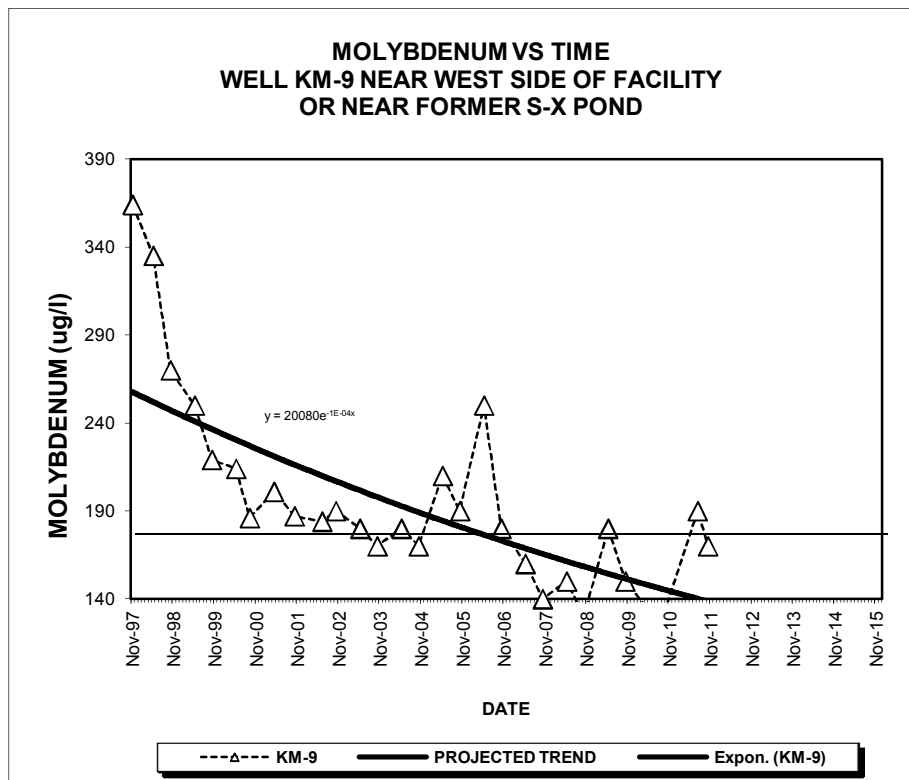


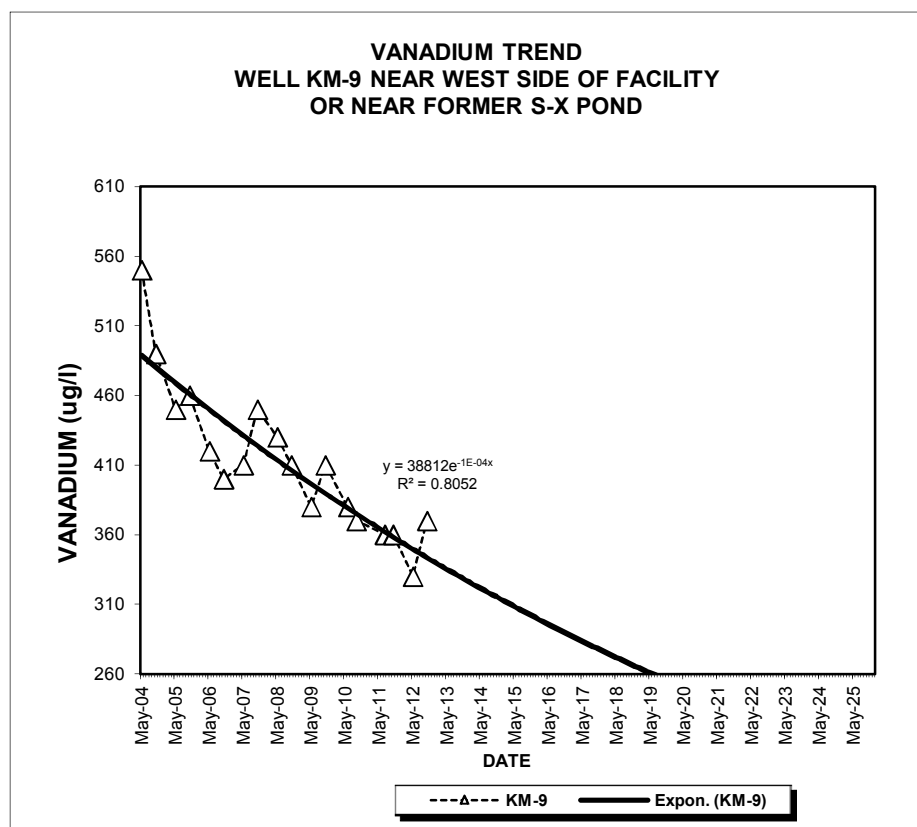
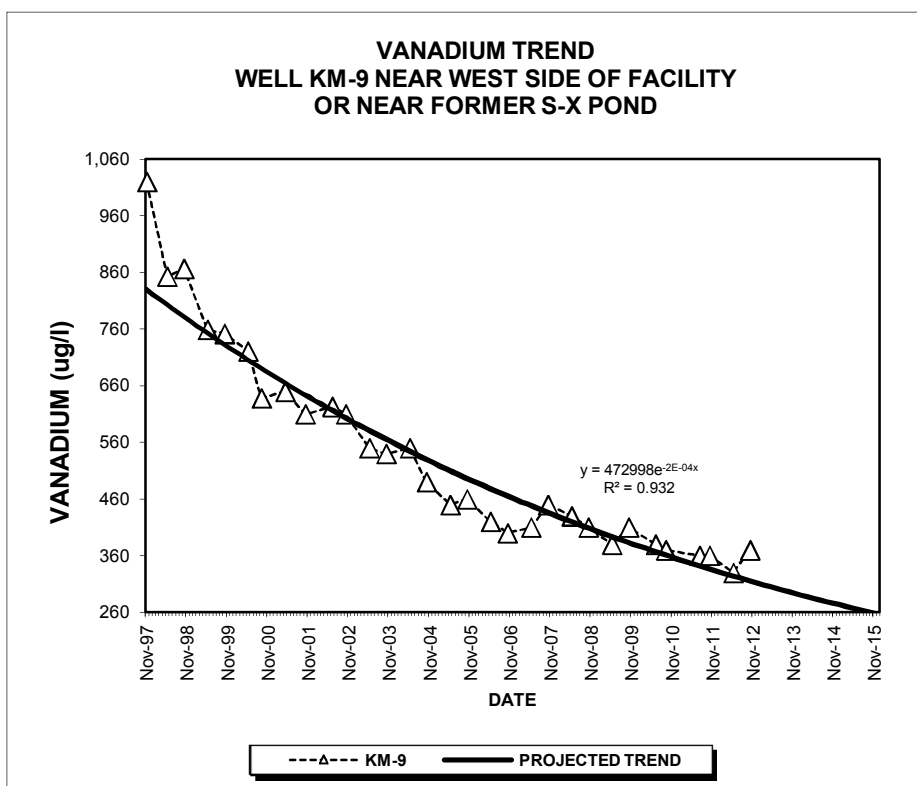


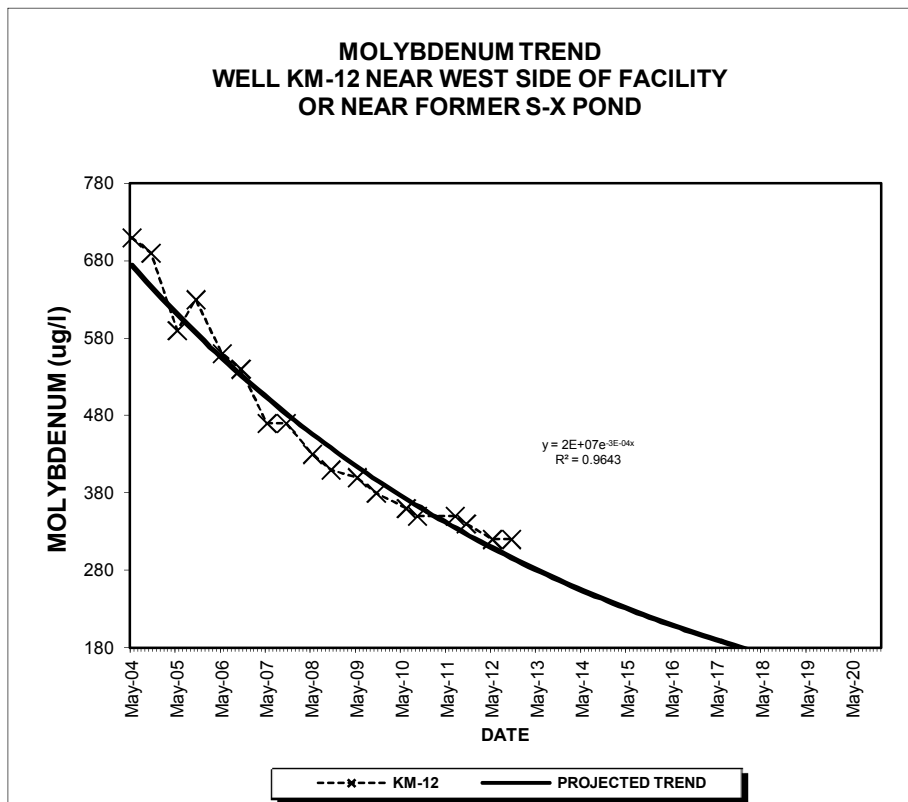
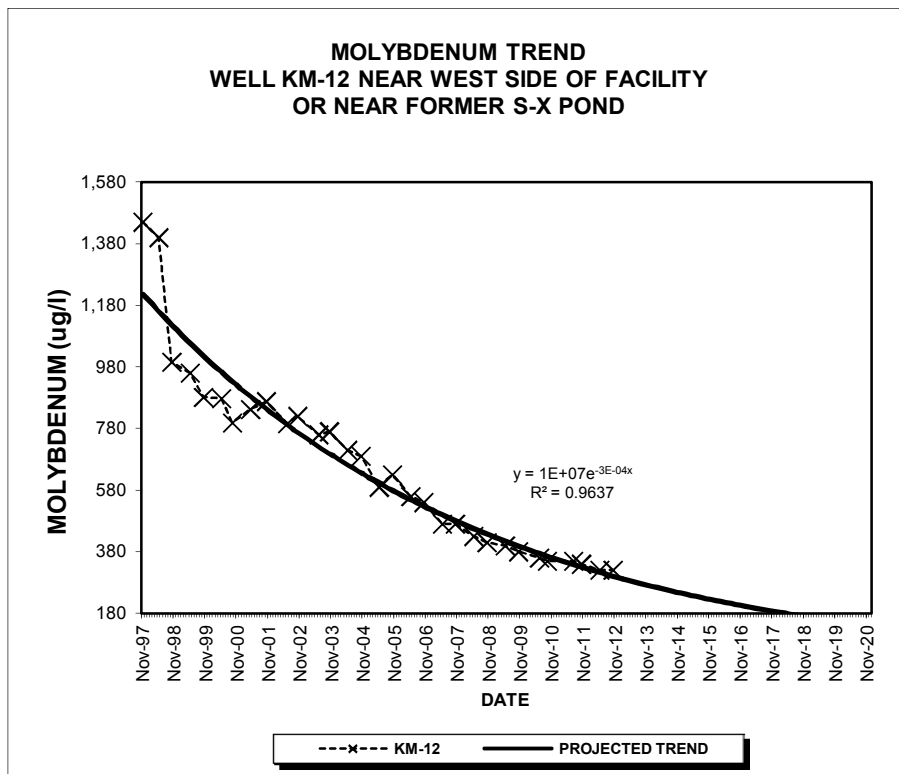


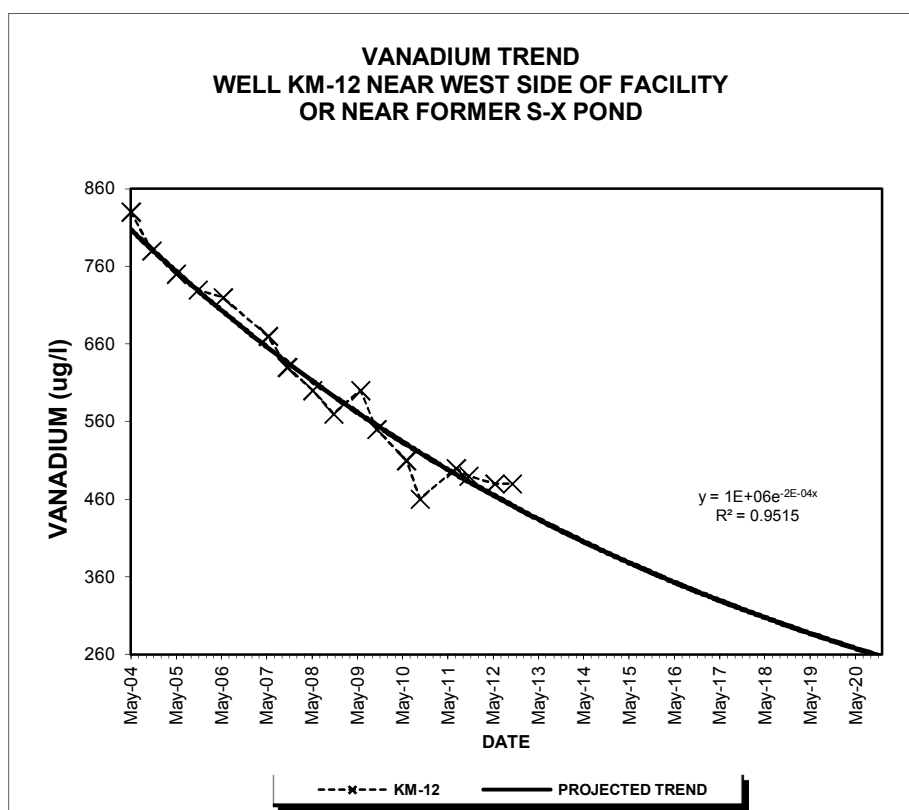
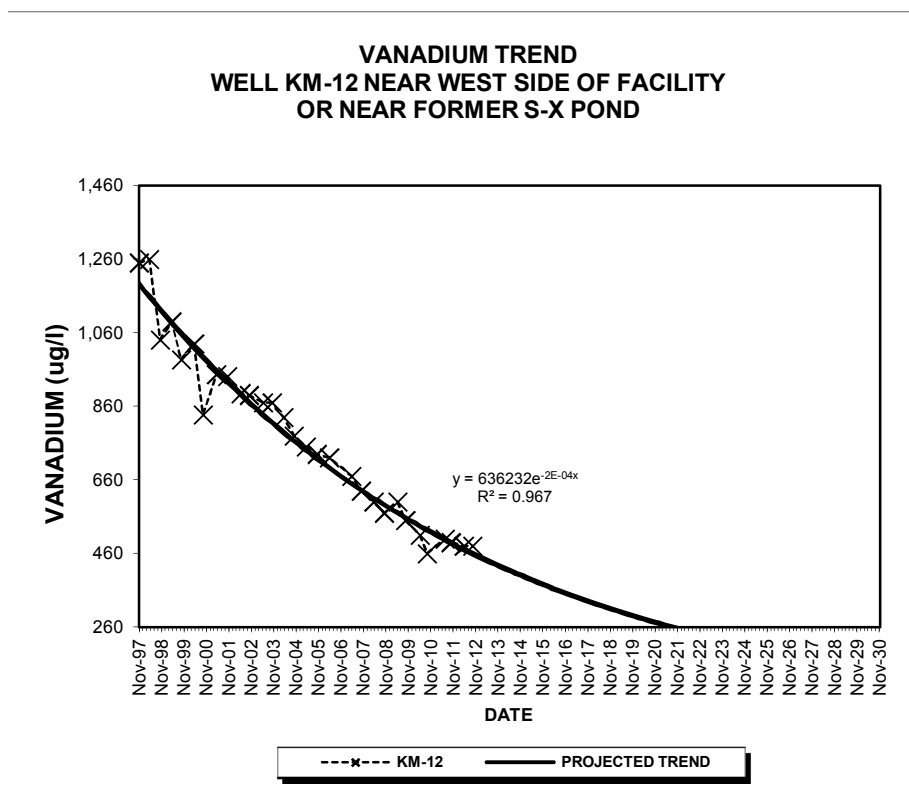


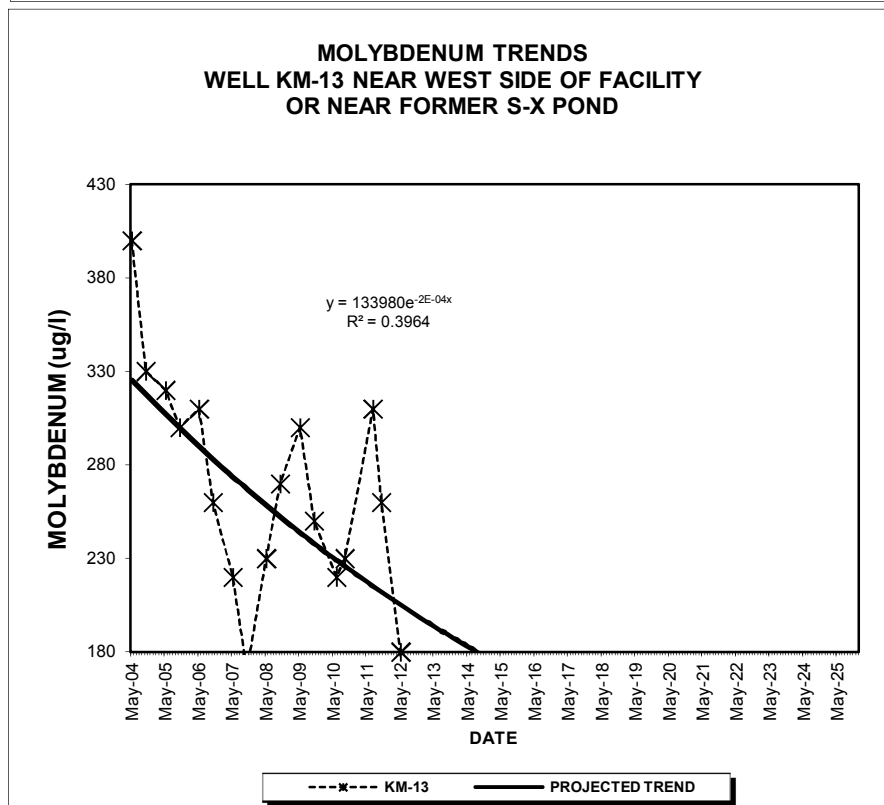
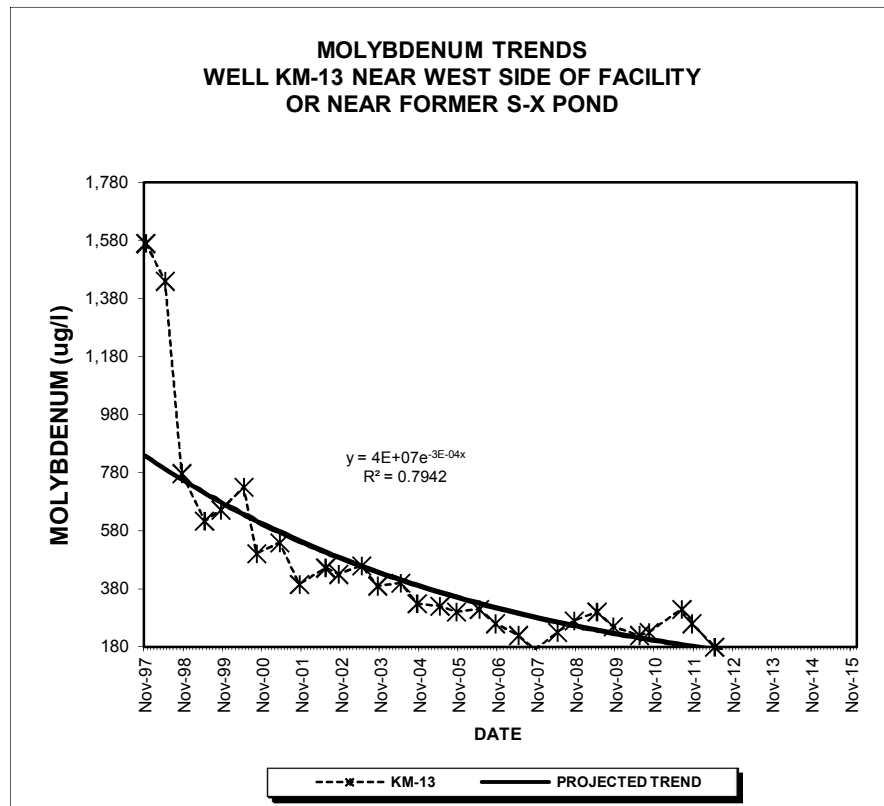


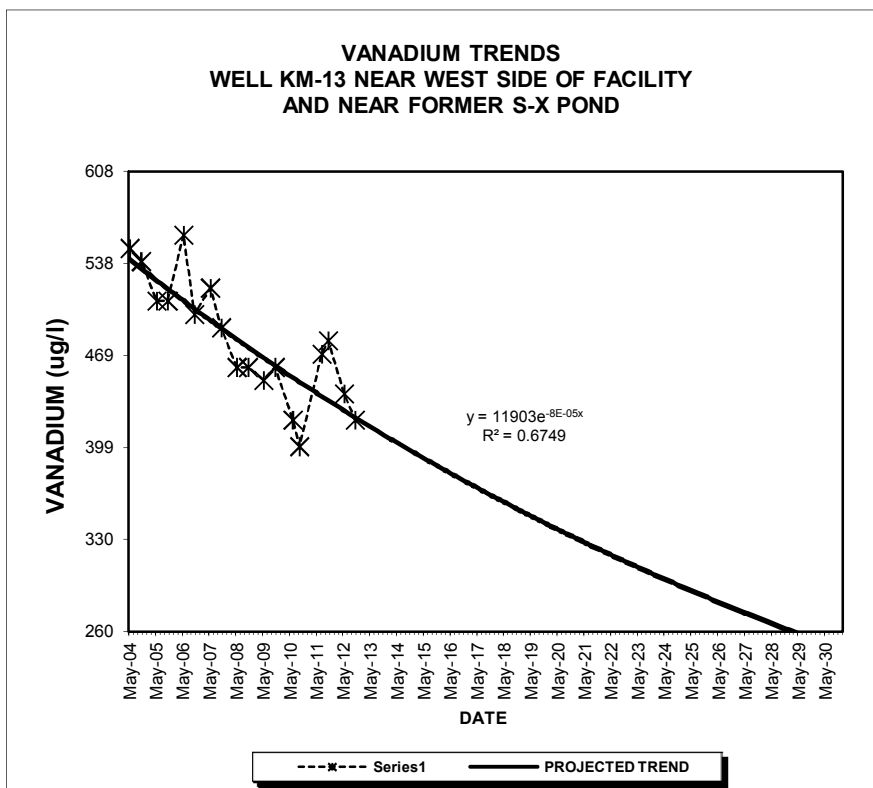
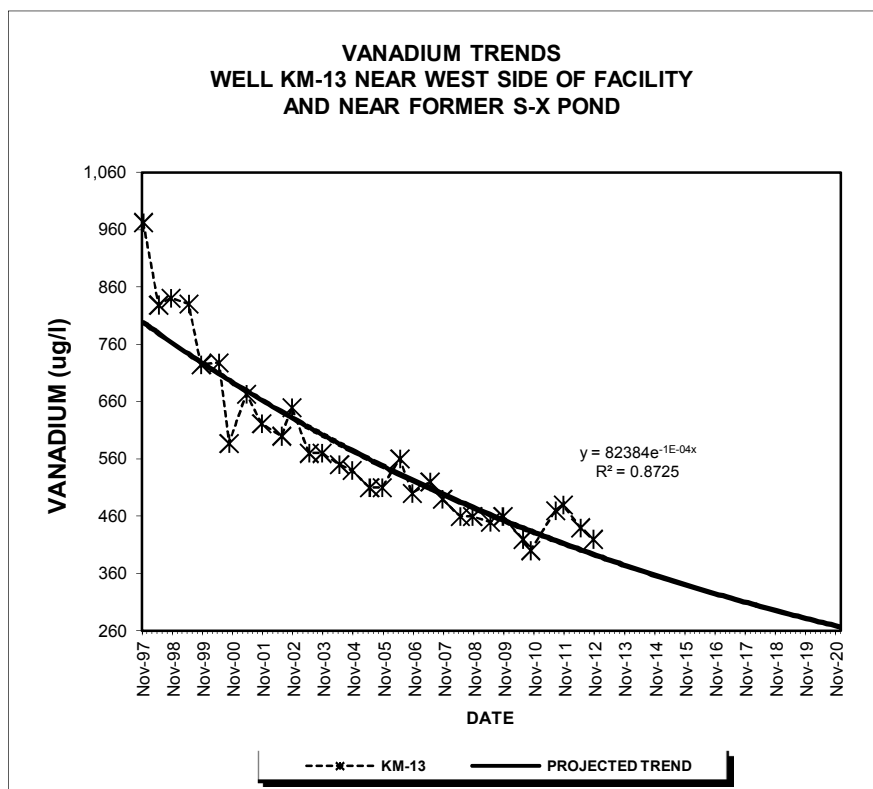


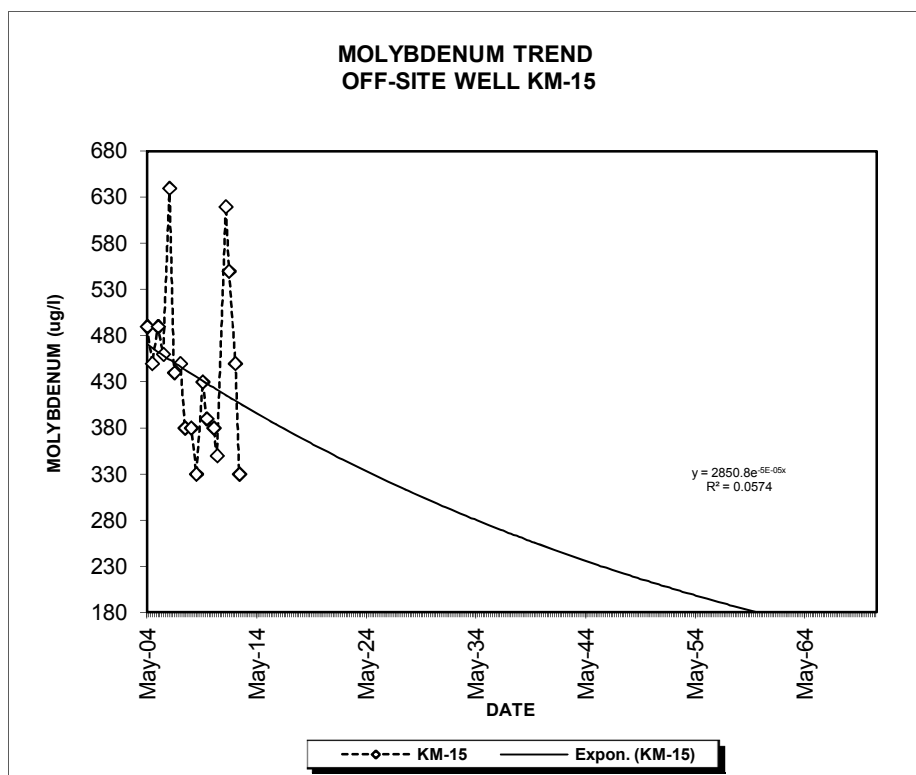
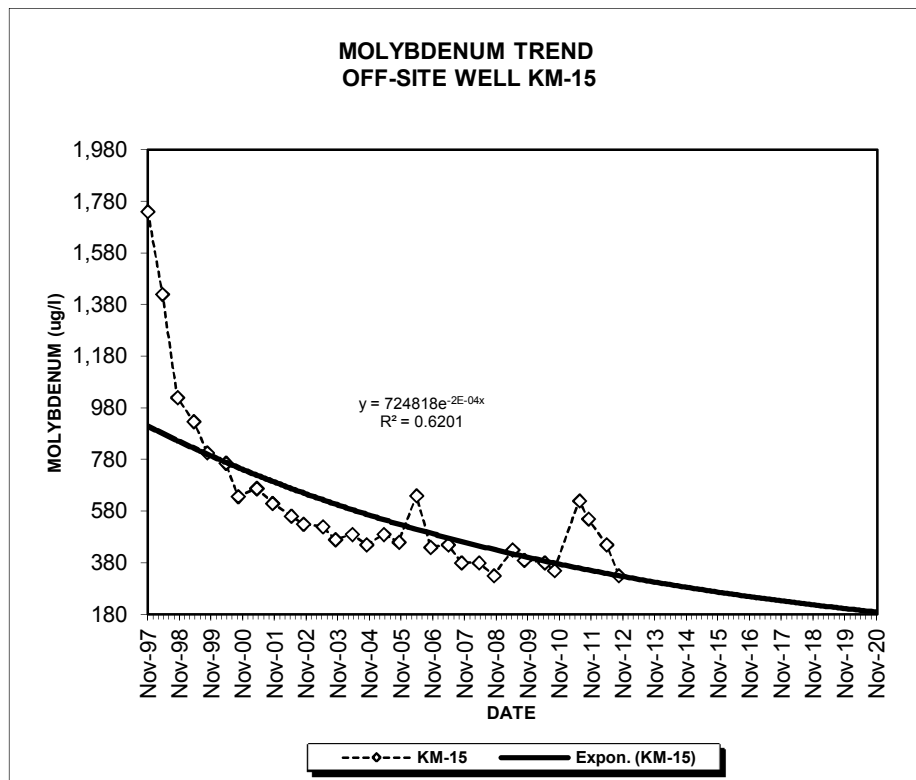


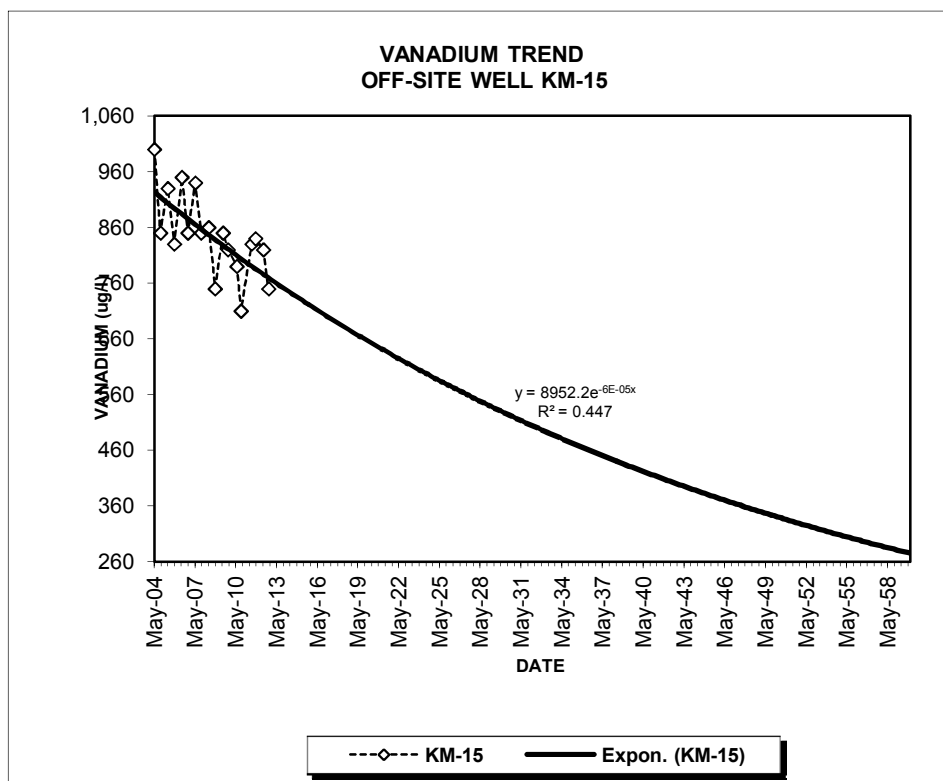
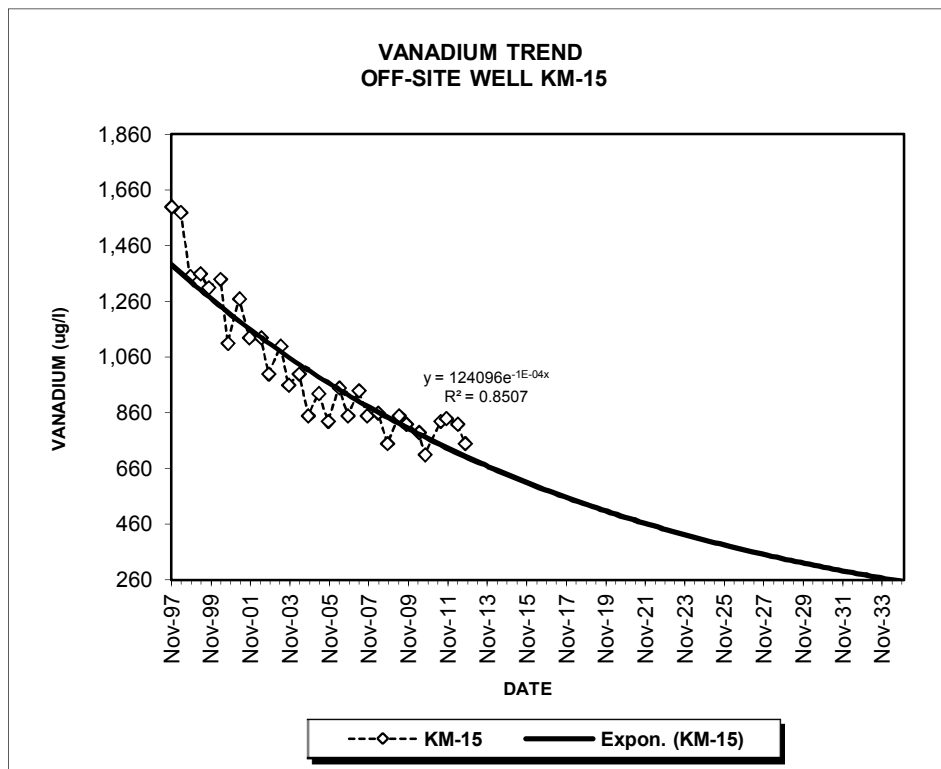


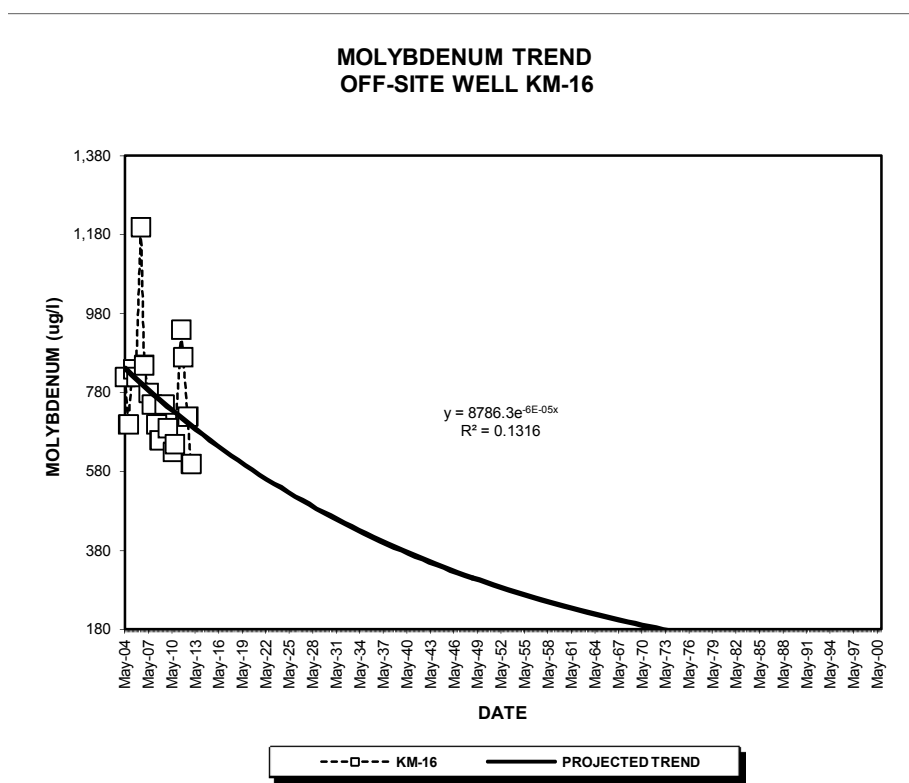
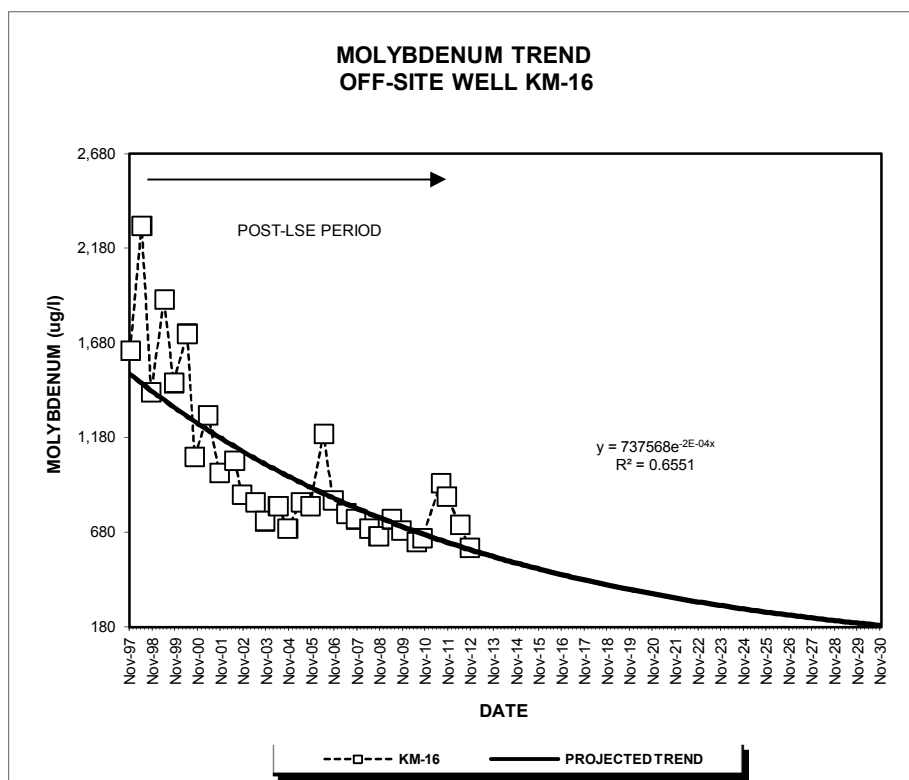


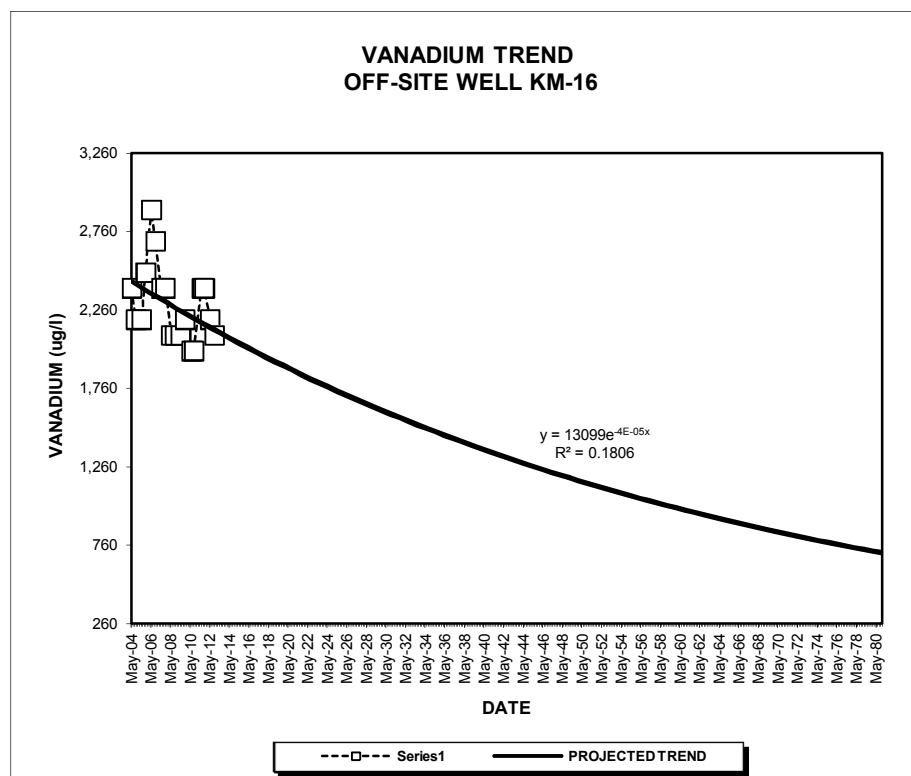
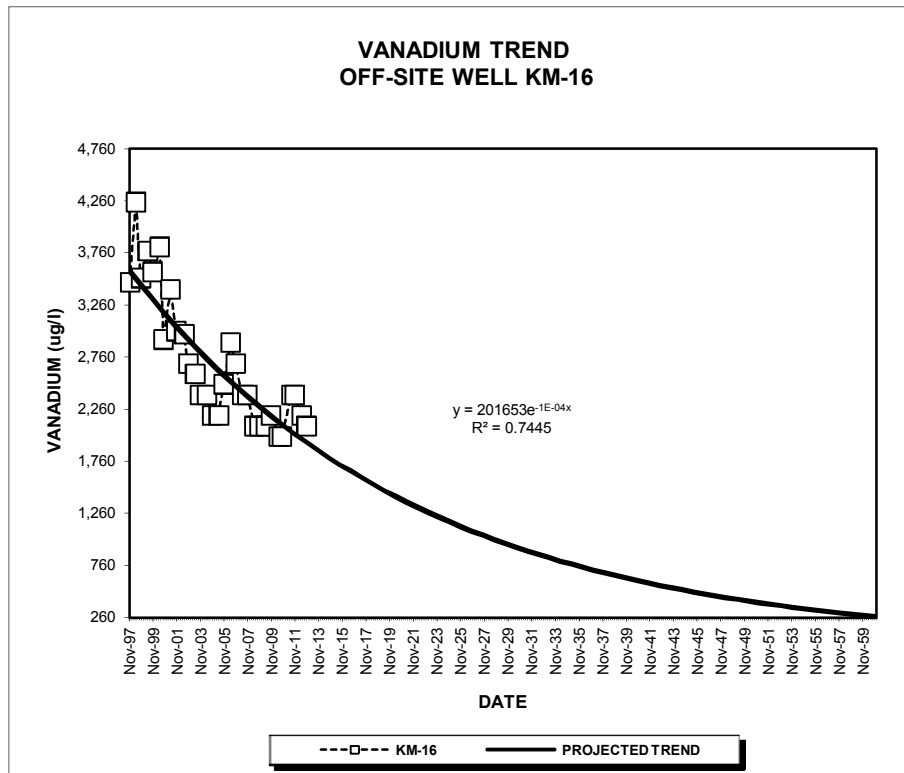


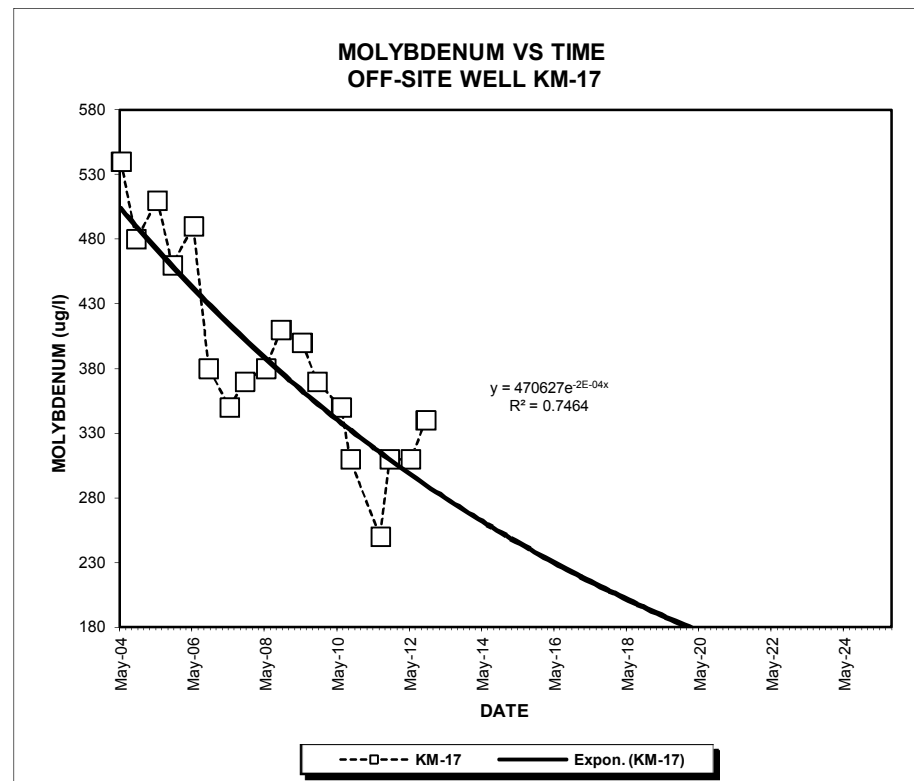
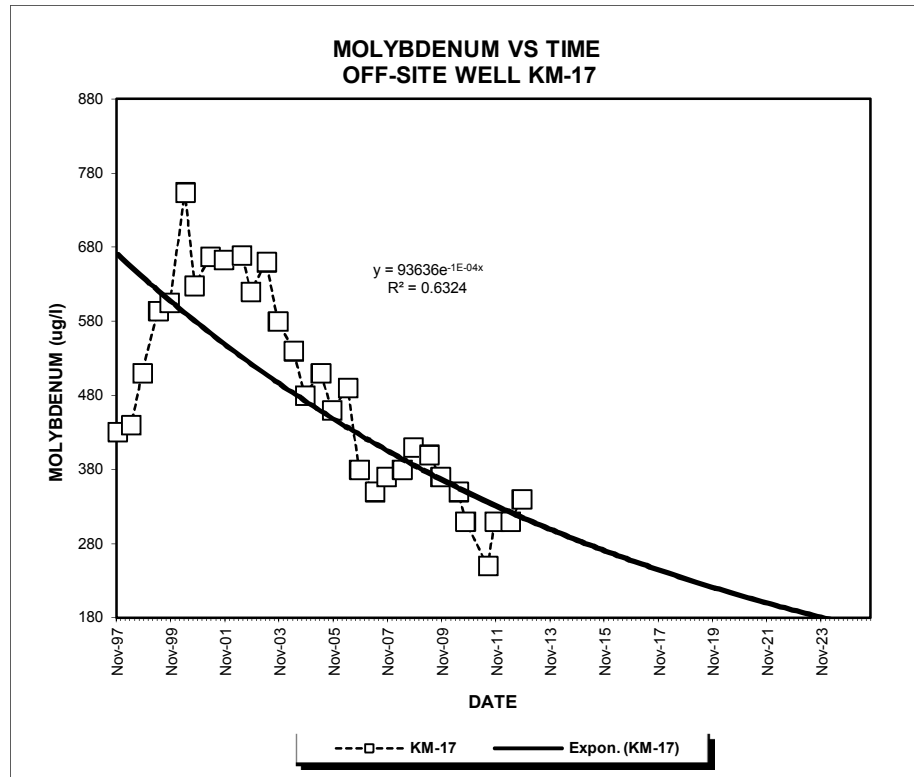


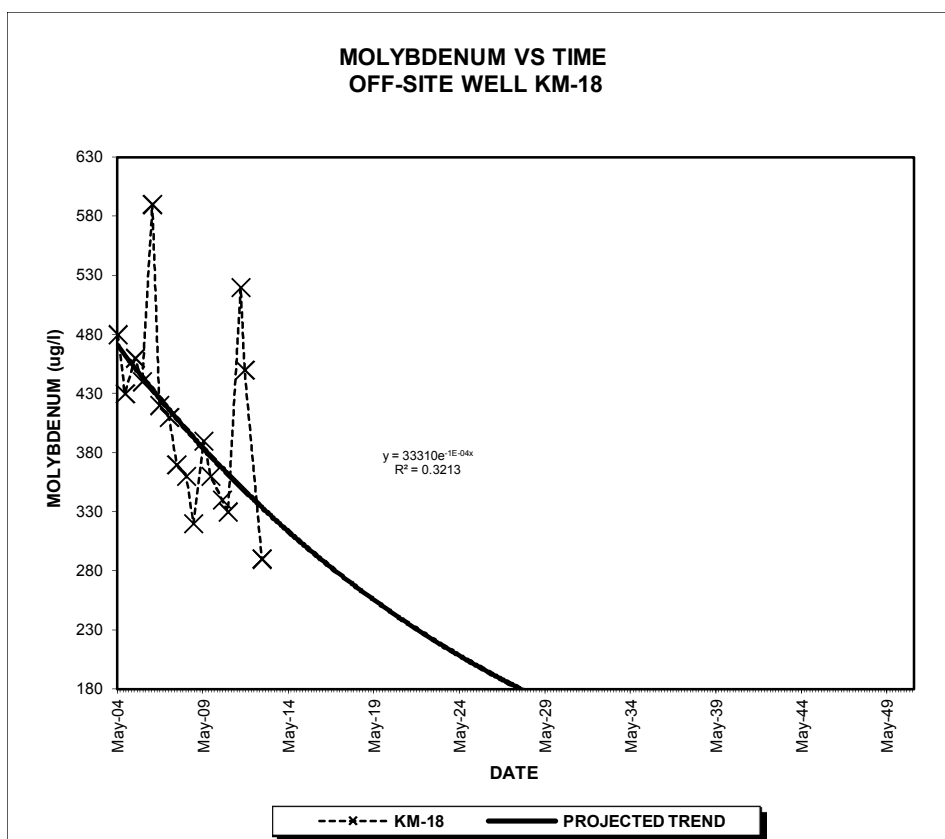
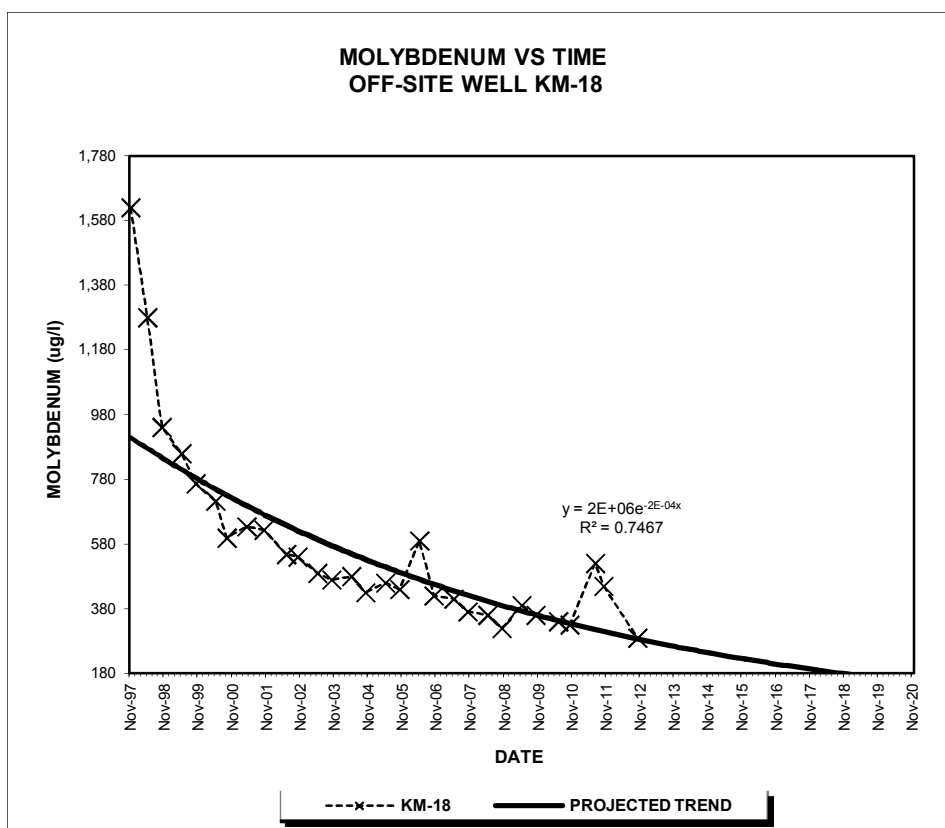










**COC CONCENTRATIONS WITH TIME
AND PROJECTED TRENDS**

**COC CONCENTRATIONS WITH TIME
AND PROJECTED TRENDS**